WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

FEBRUARY 1956

VOL. 33 No. 2 · THREE SHILLINGS AND SIXPENCE

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Regd. Trade Mark

Signal Generators...

FOR BANDS I, II & III
...ON FUNDAMENTALS

The "AVO" Signal Generator Type III

An inexpensive A.M. Signal Generator of entirely new design, for the Service Engineer. Provides six frequency bands covering 150 kc/s — 220 Mc/s. Accuracy ± 1%.

150 kc/s	—	500 kc/s	*Continuous wave or modulated at 1,000c/s. L.F. signal available for test purposes.*
500 kc/s	—	1.6 Mc/s	
1.6 Mc/s	—	5.5 Mc/s	
5.5 Mc/s	—	18 Mc/s	
18 Mc/s	—	70 Mc/s	
70 Mc/s	—	220 Mc/s	

A new type of attenuator, ensures close adherence of the output to the attenuator calibration. The instrument provides a force output of 250mV, whilst the following outputs are available via the attenuator:—

Minimum to 100 μV, x 1, x 10, x 100, x 1000.
Output impedances—80Ω, 200Ω and 400Ω.

List Price **£29**

The "AVO" Wide Band A.M./F.M. Signal Generator (Type T.F.M.)

Designed primarily for the television and F.M. Engineer, this instrument incorporates a number of additional refinements to enable it to deal satisfactorily with the very stringent requirements of the new bands.

A.M. Coverage:	5 — 220 Mc/s. in 8 ranges. CW or 400 c/s sine/square wave modulation. Accuracy ± 1%. Provision for spot frequency calibration.
F.M. Coverage:	65 — 120 Mc/s. Accuracy ± 1%. Maximum deviation ± 150 kc/s.
Output:	Minimum (about 2 μV) to 100 mV continuously variable with decade multiplier. Force output 250 mV.
Output Impedance:	80Ω, 200Ω, balanced 80Ω and 300Ω.

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Both instruments operate from 100—120, 200—260V, 50—60c/s A.C. Mains. They are light and compact, and employ double screening to ensure minimum radiation.

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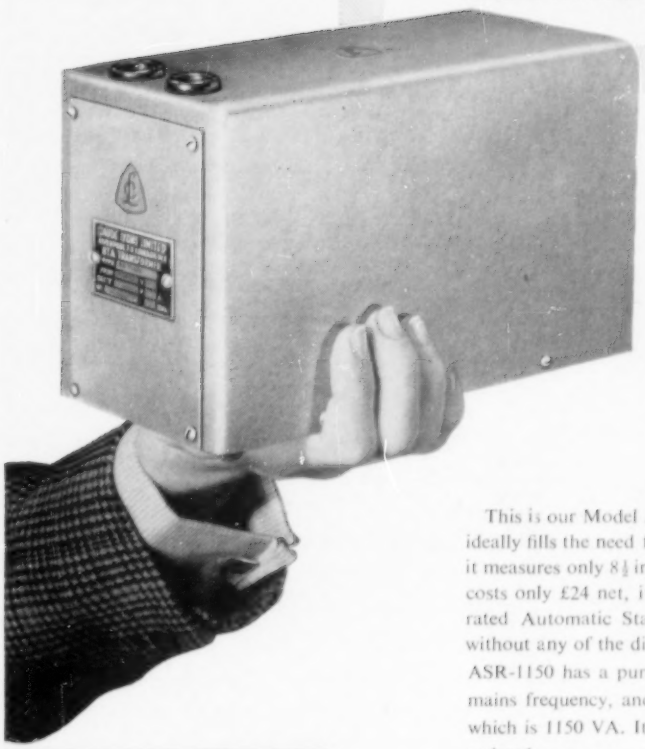

This is our Model ASR-1150 Automatic Voltage Step Regulator. It ideally fills the need for a cheap, small and light Stabiliser. Although it measures only 8½ in. × 4½ in. × 5 in., weighs as little as 11 lb., and costs only £24 net, it has a performance fully equal to any similarly rated Automatic Stabiliser of the resonated, saturated core type, without any of the disadvantages.

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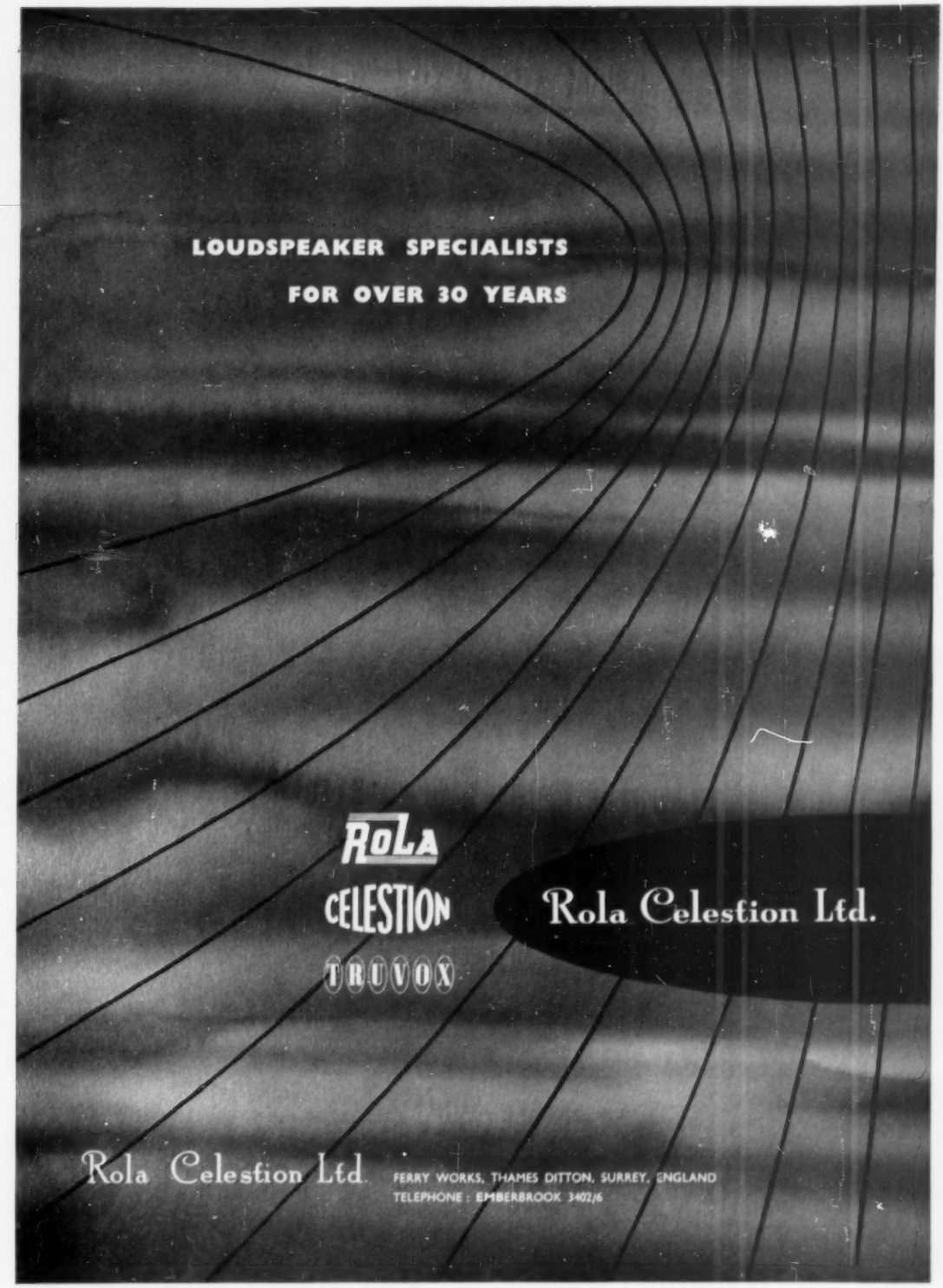
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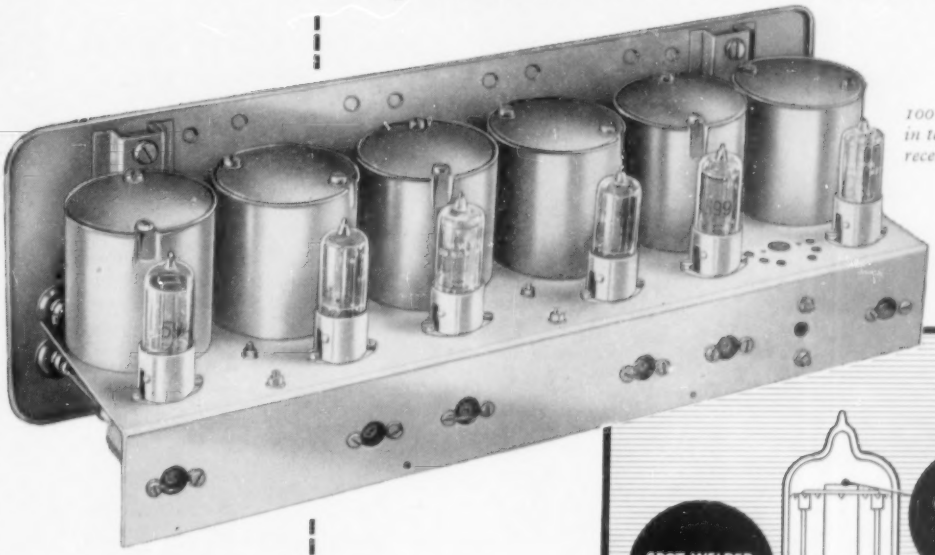
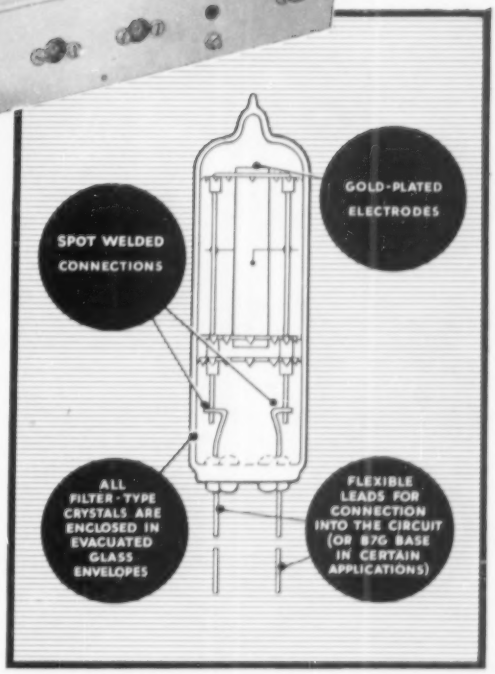


100 Kc/s crystals in telegraph receiver filter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Max. instantaneous peak current
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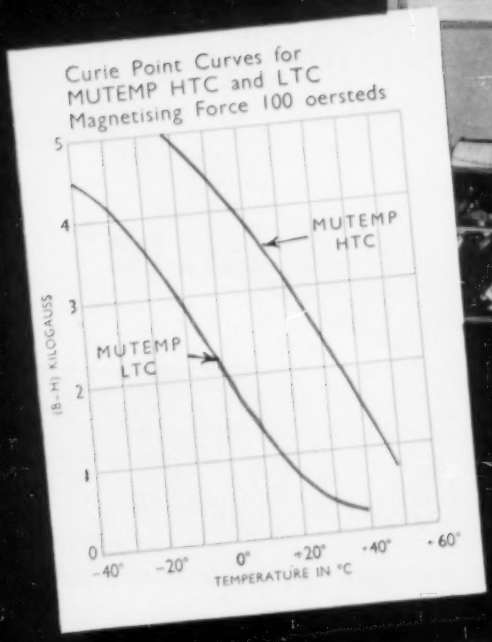
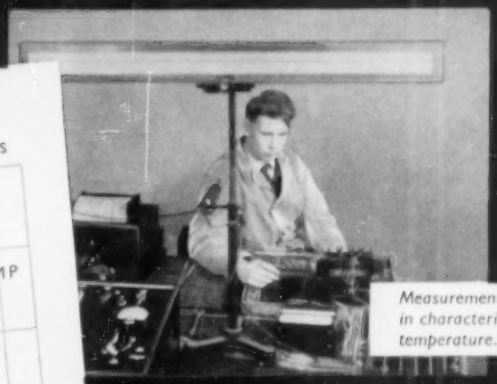
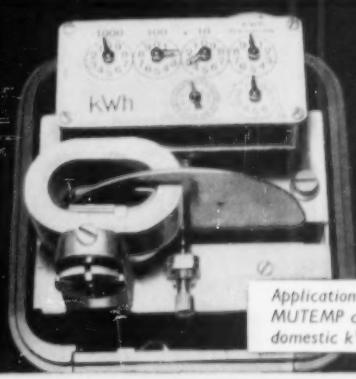




Measurement of the change in characteristics with temperature.



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This alloy, for use in electric instruments subject to wide variations in temperature, is now available in two distinct grades. The two grades ensure satisfactory coverage for a wide range of temperature change. It will be seen from the curves that MUTEMP LTC has characteristics suitable for the low temperature and HTC for the higher temperature ranges. MUTEMP is supplied in hot-rolled sheets up to 17 ins. wide and in thicknesses ranging from ·125 ins. to ·020 ins.

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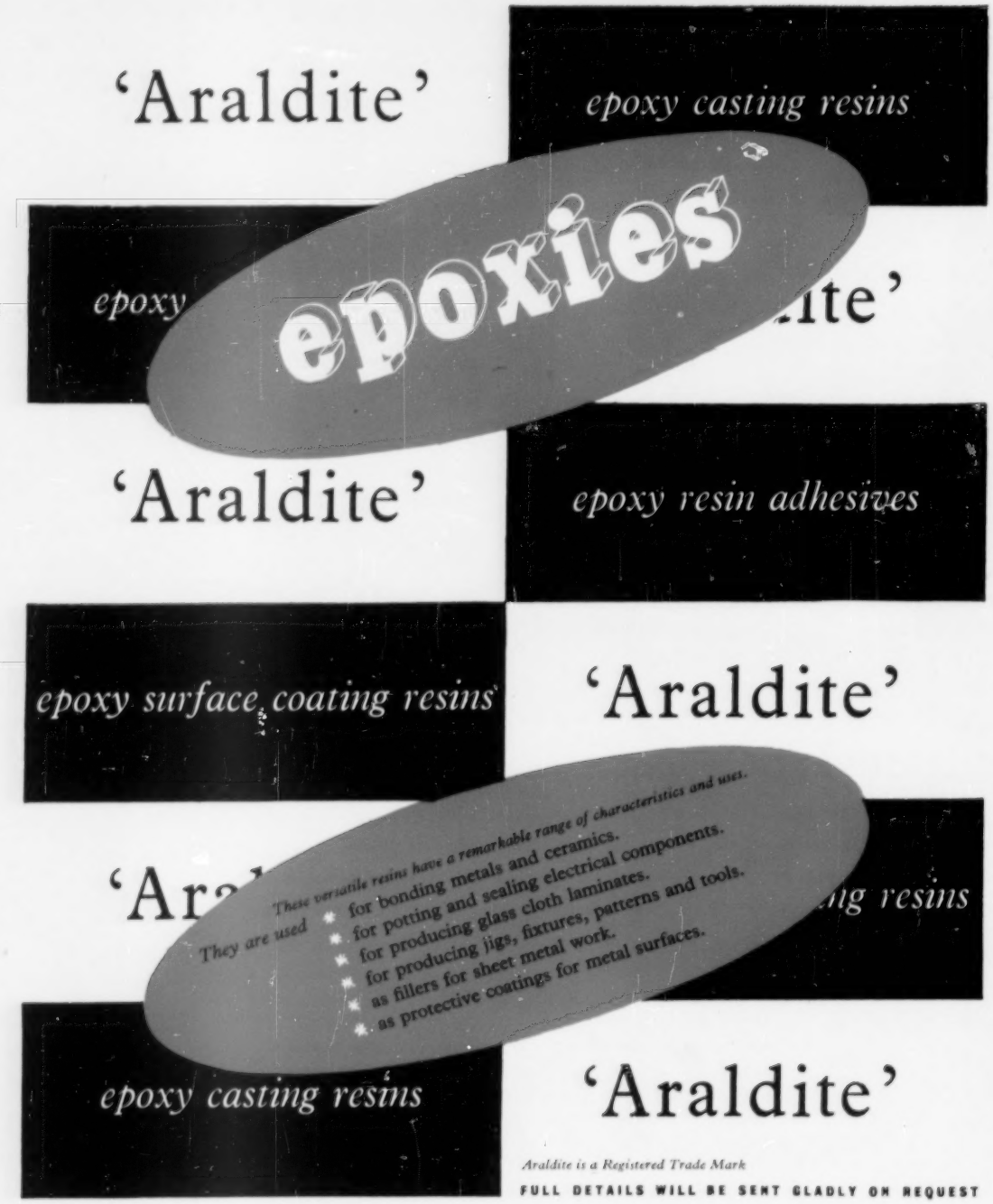

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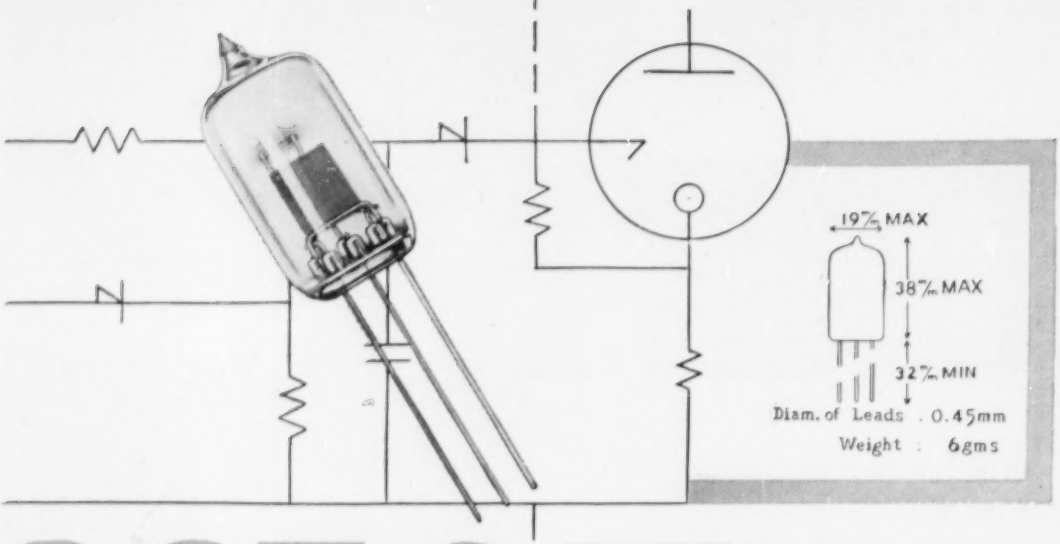
Osram VALVES

Cold Cathode Triode



CCT6

Specially designed for circuit applications in which sequential switching is achieved by the transfer of voltage level in the steady state from one valve to the next. **List Price:—25/- Tax free.**

Ratings

Anode supply voltage range . . . . . 190-250 Volts

Normal anode operating current range . . . . . 1- 5 mA

Peak anode current — maximum . . . . . 40 mA

Circuit Limits

The following circuit specification limits are those which would apply to the valve up to the point of failure in service.

Control gap breakdown voltage . . . . . 70 — 90 Volts
(Anode open circuited
Trigger load 47KΩ)

Main gap breakdown voltage . . . . . 250 Min. Volts
(Trigger connected to cathode through 470KΩ) (Suddenly applied)

Main gap breakdown voltage . . . . . 250 Min. Volts
(Trigger biased +60V with respect to cathode through 470KΩ) (Suddenly applied)

Main gap maintaining voltage at I_a = 5mA . . . . 65 — 80 Volts
(Trigger open circuited)

For further details write to the Osram Valve and Electronics Department

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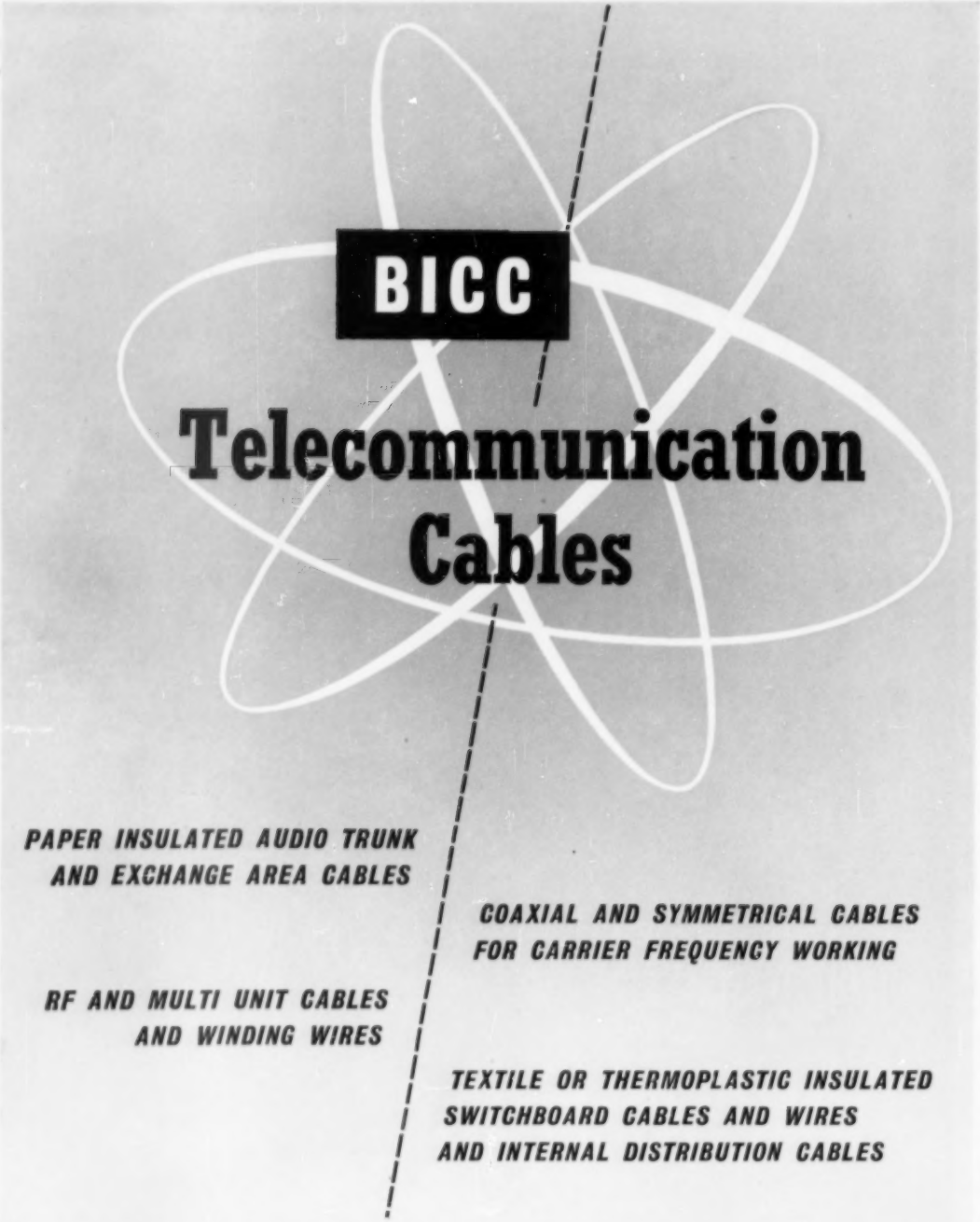
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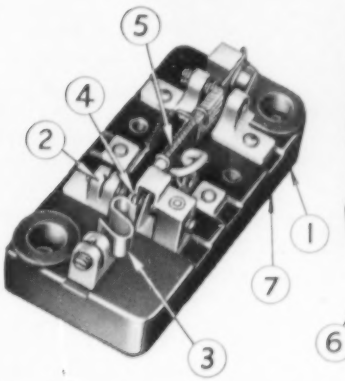
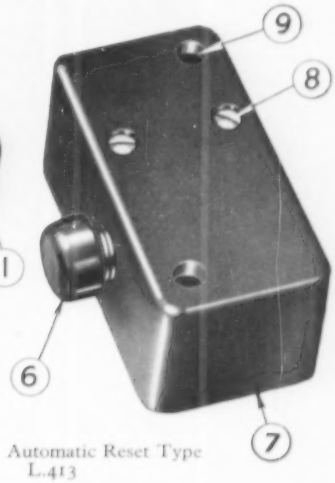


Hand Reset Version L.415



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2 Short rigid contact and support pillars.

3 Hardened beryllium copper spring gives quick make and break with follow-through action.

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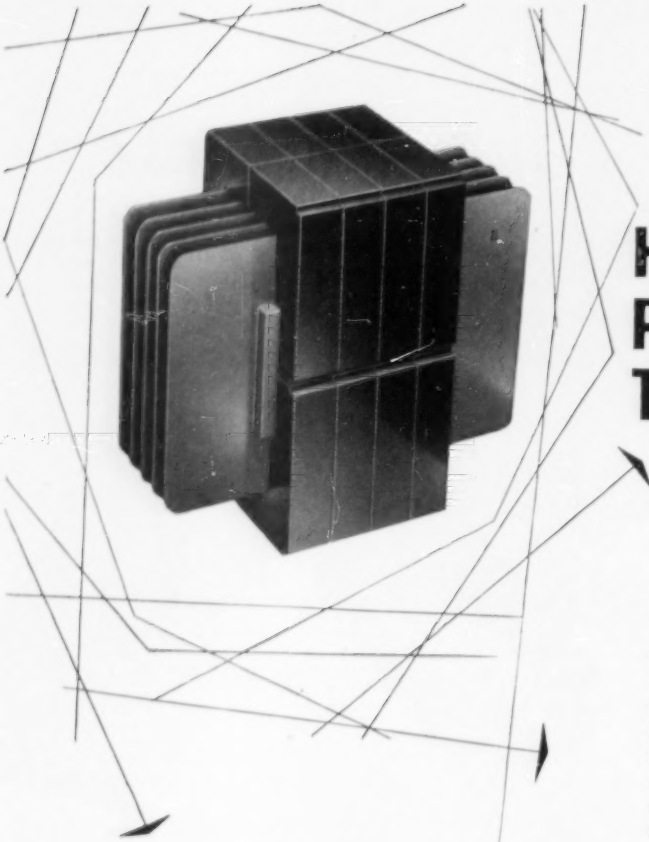

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Volume 33 · Number 2

CONTENTS

FEBRUARY 1956

Editorial: The Transistor Amplifier 31

Glow-Discharge Tubes
by F. A. Benson, M.Eng., Ph.D. and L. J. Bental, B.Sc., Dipl.Ing. 33

Compatible Colour-Television (*Conclusion*)
by J. Haantjes and K. Teer 39

Arrival Angle of H. F. Waves
by A. F. Wilkins, O.B.E., M.Sc. and C. M. Minnis, M.Sc. .. 47

Correspondence 53

New Books 55

Standard-Frequency Transmissions 56

Abstracts and References. Nos. 305-640 .. .. A.25-A.48

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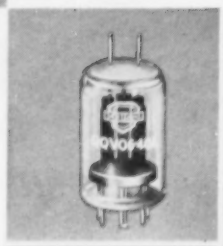

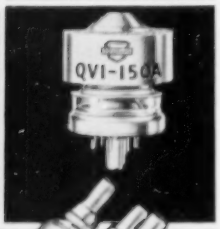

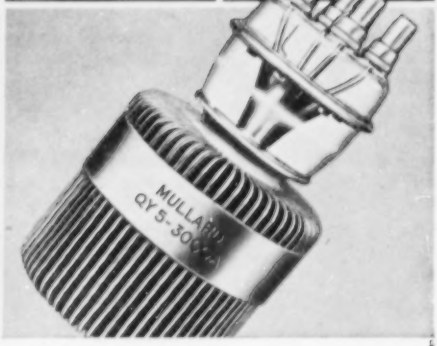

PRINCIPAL CHARACTERISTICS

MULLARD TYPE No.	AMERICAN TYPE No.	CV TYPE No.	DESCRIPTION	BASE	HEATER (V)	HEATER (A)	$V_{amax.}$ (V)	$p_{amax.}$ (W)	TYPICAL LOAD POWERS (W)	TYPICAL LOAD FREQUENCIES (Mc/s)
QV06-20	6146	CV3523	V.H.F. Power Tetrode	Octal	6.3	1.25	600	20	42 20	60 175
QQV03-10	6360	CV2798	V.H.F. Power Double Tetrode	B9A	6.3 12.6	0.83 0.42	300	2 x 5.0	14 11.5	100 200
QQV03-20A	6252	CV2799	V.H.F. Power Double Tetrode	B7A	6.3 12.6	1.3 0.65	600	2 x 10	39 15	200 600
QQV06-40A	5894	CV2797	V.H.F. Power Double Tetrode	B7A	6.3 12.6	1.8 0.9	750	2 x 20	72 45	200 500
QY3-65	4-65A	CV1905	V.H.F. Power Tetrode	B7A	6.0	3.5	3000	65	224 88	50 220
QY3-125	6155/4-125A	CV2130	V.H.F. Power Tetrode	B5F	5.0	6.5	3000	125	300 175	120 200
QY4-250	6156/4-250A	CV2131	V.H.F. Power Tetrode	B5F	5.0	14.1	4000	250	800 400	75 120
QV1-150A	4X-150A	CV2519	U.H.F. Power Tetrode	B8F	6.0	2.6	1250	150	156 112	165 500
QY5-3000A	6076	—	V.H.F. Power Tetrode	Special 4-pin	6.3	32.5	5000	3000	3300 *3500	75 220

* 2 Valves in push-pull. Television service.

Mullard MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT181

WIRELESS ENGINEER

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The Transistor Amplifier

IT is well known that the inclusion of an unbypassed resistor in the cathode circuit of a thermionic valve reduces the voltage amplification considerably. The external behaviour of a transistor is closely analogous to that of a valve and one naturally expects, therefore, that the influence of such a resistance in the emitter circuit would have a similar effect.

In practice, it is usually found that it does reduce the amplification, but not always as much as one expects. Sometimes the reduction is large; sometimes it is quite small. In theory, however, the usual formula shows that the current amplification should be very little affected by an emitter resistance.

There thus seems to be a contradiction between theory and practice. As usual in such a case, it turns out that the theory is incomplete or incorrectly applied.

Fig. 1.

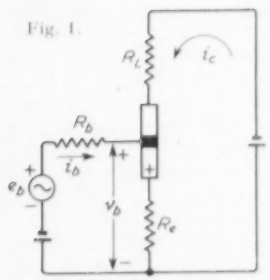

Fig. 1 shows the circuit of a p-n-p junction transistor with an emitter resistance R_e, working into a load resistance R_L and fed from a source of e.m.f. e_b having an internal resistance R_b. Fig. 2 shows one form of equivalent circuit. In this, we have used the symbol ρ for the internal resistances, since r is commonly employed for the earthed-base connection. The relevant equations are:—

$$e_b = i_b R_b + v_b$$

$$v_b = i_b(\rho_b + \rho_e + R_e) + i_c(\rho_e + R_e)$$

$$i_b\rho_m = i_c(\rho_c + \rho_e + R_e + R_L) + i_b(\rho_e + R_e)$$

whence

$$A_c = \frac{i_c}{i_b} = \frac{\rho_m - \rho_e - R_e}{\rho_c + \rho_e + R_e + R_L}$$

and

$$\rho_{in} = \frac{v_b}{i_b} = \rho_b + (\rho_e + R_e)(1 + A_c)$$

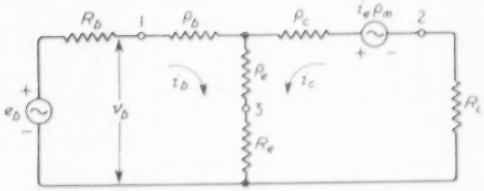

Fig. 2.

In practice, the current amplification factor a is more often quoted than ρ_m. This is, in effect, the value of A_c when $R_e = R_L = 0$. Therefore, $\rho_m - \rho_e = a(\rho_c + \rho_e)$ and we can write

$$A_c = \frac{a(\rho_c + \rho_e) - R_e}{\rho_c + \rho_e + R_e + R_L}$$

Generally, $\rho_e \ll \rho_c$ and R_e will not often be comparable with $a\rho_c$ or $\rho_c + R_L$. For example, we might have $\rho_b = 500\ \Omega$, $\rho_e = 7\ \Omega$, $\rho_c = 13\ \text{k}\Omega$ and $a = 45$. The load R_L is generally of the order of 1 kΩ and R_e will not often be more than 1 kΩ. Therefore, with $R_e = 0$, we have $A_c = 585/14 = 41{\cdot}8$ and with $R_e = 1\ \text{k}\Omega$ we have $A_c = 584/15 = 39$. Even with R_e as great as 10 kΩ the amplification would drop only to 24. The change is much less than one seems to get in practice.

The equations show that the current amplification, as defined, is nearly independent of R_e over

the normal range of component values. If the input circuit of the transistor is so arranged that i_b is constant, then i_c will hardly be affected by R_e and it is unnecessary to bypass R_e. If the input voltage v_b is kept constant, however, matters are very different. Then $i_b = v_b/\rho_{in}$ and ρ_{in} depends on R_e.

Taking the values given, with $R_e = 0$ we have $\rho_{in} = 0{\cdot}5 + 0{\cdot}007 \times 42{\cdot}8 = 0{\cdot}8$ kΩ, while with $R_e = 1$ kΩ, we find $\rho_{in} = 0{\cdot}5 + 1{\cdot}007 \times 40 = 40{\cdot}78$ kΩ. The input currents are changed in the ratio of $40{\cdot}78/0{\cdot}8 \approx 51$.

This is, therefore, the explanation of why the apparent gain of a transistor stage depends quite markedly upon R_e, although the true current gain as normally defined is hardly affected. It becomes, too, clear why the magnitude of the effect seems to vary, for it depends upon the resistance of the source feeding the transistor; that is, upon the value of R_b in Figs. 1 and 2.

Expressed in this way, the mechanism appears quite different from that in a thermionic valve. There, the grid–cathode voltage is the difference between the input and cathode voltages, so that increasing the last by increasing a cathode resistance reduces the gain because it reduces the grid–cathode voltage. Actually, however, precisely the same effect occurs in the transistor. Referring to Fig. 2, the true input voltage to the transistor is the voltage between 1 and 3 and v_b is really the input voltage of the amplifier stage, not of the transistor itself. The voltage between 1 and 3 is $v_b - (i_b + i_c)R_e$ and falls as the emitter voltage increases with increasing R_e.

There is a difference between the valve and the transistor in practice, however, in that the value of the source impedance plays a large part in the action. Even this is not foreign to the valve, though, for in the feedback circuit of Fig. 3 the voltage amplification between grid and anode is substantially independent of the feedback resistance R_f. The input resistance becomes quite low because of R_f, however, and affects the voltage which can be developed on the grid from a source of given impedance.

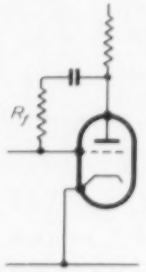

Fig. 3.

Reverting to the transistor, the input current is

$$i_b = \frac{e_b}{R_b + \rho_{in}} = \frac{e_b}{R_b + \rho_b + (1 + A_c)(\rho_e + R_e)}$$

If we bypass R_e we can replace this term by $Z_e = R_e/(1 + j\omega C_e R_e)$ and, treating A_c as a constant, we get as the ratio of output at any frequency to the output at infinite frequency ($Z_e = 0$).

$$S = \sqrt{\left[\frac{B^2 + \omega^2 C_e^2 R_e^2}{1 + \omega^2 C_e^2 R_e^2}\right]}$$

Where

$$B = 1 + \frac{(1 + A_c)R_e}{R_b + \rho_b + (1 + A_c)\rho_e}$$

This expression is exactly the same as the one given by Sturley[1] for the valve save that, in his case, the value of B is $1 + R_k(1 + \mu)/(r_a + R_L)$. The family of universal curves which he gives (his Fig. 9.10) is, therefore, applicable also to the transistor. Using the values given earlier with $R_b = 5$ kΩ we have $B = 8{\cdot}35$ for $R_e = 1$ kΩ. Interpolating from Sturley's curves we find $\omega C_e R_e$ must be about 11 for a drop in response of 2 dB. At 50 c/s, $C_e R_e = 11/314 = 0{\cdot}035$ in farads and ohms. So for $R_e = 1$ kΩ, we need $C_e = 35\ \mu$F, which is the same sort of value that one would use with a valve.

We thus conclude that a transistor requires that any emitter circuit resistance should be bypassed to avoid a loss of effective gain under normal conditions. If the source impedance of the base circuit can be kept high enough, however, bypassing can become unnecessary.

W.T.C.

[1] K. R. Sturley, "Radio Receiver Design", Part 2, p. 20 (1st Edn.), Chapman & Hall.

GLOW-DISCHARGE TUBES

Initial Drift and Running-Voltage/Temperature Characteristics

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(The University of Sheffield)

SUMMARY.—Measurements have been made to determine the influence of various tube parameters on the magnitude and duration of the initial drifts and on the running-voltage/temperature curves of glow-discharge stabilizers. Tubes differing in cathode material, gas filling, gas pressure and construction have been specially manufactured for the investigations. The results of the work are presented here and discussed.

Introduction

DURING recent years the demand for glow-discharge voltage-regulator tubes of high stability has risen considerably. It is well known that such tubes form simple and inexpensive methods of voltage stabilization and are also extensively used in electronic stabilizers of the degenerative type for providing a reference voltage. For both these purposes the ideal tube should, among other things, have no drift in running voltage, either due to changes in temperature or other causes, when operated for any length of time.

A good deal of information is now available on the behaviour of certain tubes when operated under conditions of varying ambient temperature[1–9] and many measurements have also been made of the high rate of drift in running voltage which occurs in all tubes during the first few minutes of operation after striking[2–6].

The maximum and average temperature coefficients of running voltage for many tubes of various types have previously been reported by Benson, Cain and Clucas[1] and Benson[2–5]. In all these cases the tubes were run at constant current through a variation of ambient temperature from about 20°C to something approaching 100°C by placing them in either a water bath or an electrically-heated oven. It was then assumed, in order to calculate the temperature coefficient of each tube, that the change of running voltage between these two temperatures was linear. Most of the tubes so tested exhibited a negative temperature coefficient (i.e., the running voltage dropped as the temperature was increased) although three types showed positive ones. Tubes of the same type gave widely different results and some tubes had a nearly-constant running voltage throughout the whole temperature range. Kirkpatrick[6] has made measurements on five tubes of each of the American types VR75, VR105 and VR150 as the temperature of the insulated box in which they were placed was raised to 100°C. The voltage across one tube of each type was recorded continuously during the tests and measurements were made on the other tubes only at room temperature, at 100°C and then again at room temperature. From these readings an average temperature coefficient was computed, except in the case of the VR105 type where the changes in tube voltages with temperature were too erratic for this to be possible.

It has also been suggested[7] that some tubes have temperature coefficients which are of opposite signs for deviations above and below room temperature and this has been confirmed for a small number of tube types by Benson and Bache[8].

Further detailed and more recent measurements have been carried out by Benson and Mayo[9] on a number of other tube types. Running-voltage/temperature characteristics of nine British types of tube and one German type have been given and discussed by them. Many of these curves exhibit minima; i.e., the temperature coefficient of running voltage changes from negative, through zero, to positive values. It was concluded from this work that the kind of gas filling appears to be an important factor in deciding whether a given tube will show a positive or a negative temperature coefficient. The assumption, that the change of running voltage with temperature is linear, made in previous calculations to determine temperature coefficients, is not, in general, valid when the coefficient shows a change of sign.

The authors have now investigated, in detail, the effect of changing various tube parameters on the magnitude and duration of the initial drift and on the running-voltage/temperature curve. For this purpose many of the tubes examined had to be specially manufactured so that the influence of one parameter at a time could be observed. Tests have been carried out on a large number of tubes differing in cathode material, gas filling, gas pressure and construction. The results of the work are presented here and discussed.

Measurements

The methods used for measuring the initial drift and running-voltage/temperature characteristic have already been described[3, 9].

MS accepted by the Editor, March 1955

*Now with Elliott Bros., Ltd.

Each tube was fed in turn from a d.c. supply through a suitable series resistor. A meter in the anode lead was used to measure the current while decade resistance boxes across the tube stepped down the running voltage so that it could be measured on a vernier potentiometer. The ambient temperature was varied by immersing the tube in an electrically-heated oil bath (a special stirring device was used to maintain a uniform temperature in the bath).

In order to obtain further information a number of new commercial tubes have been tested, differing in gas filling and in cathode material.

Some typical results of these tests are given in Fig. 1. To give a clear picture, only one curve has been plotted for each type of tube, representing the mean running-voltage/temperature characteristic. Also the running voltage at 30°C has arbitrarily been chosen as the zero point for change of running voltage. The characteristics

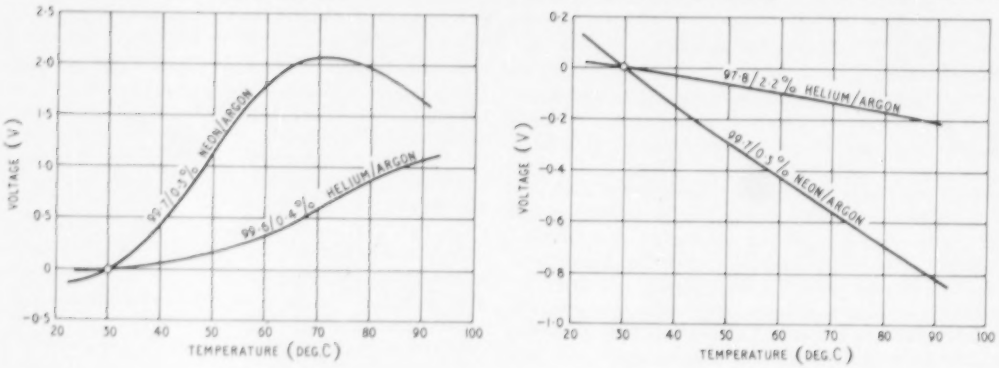

Fig. 1. *Voltage/temperature characteristics of commercial stabilizers having nickel cathodes (a) and with cerium-alloy cathodes (b).*

It should be noted that while each tube was operated at a suitable mean current, the input voltage was kept constant and not the current. This was achieved by using a regulated power supply with a stabilization of 0·2%. Change of temperature produced a variation in the running voltage and in the current through the tube (the latter being small in practice). Thus the tubes were operated under conditions similar to those met with in practice.

In each case the tube was operated at room temperature until the initial drift was complete (in several cases drifts for periods over six hours have been observed). After this the bath was heated in steps of about 10°C up to a temperature approaching 100°C. Before each reading was taken the temperature was kept constant for a few minutes to allow a steady running voltage to be reached.

Experimental Results

(1) *Commercial Stabilizers*

A number of commercial tubes had already been tested before the present measurements were made. The results obtained[9] seemed to suggest that the gas filling of the tube had a marked effect on the running-voltage/temperature characteristic as mentioned earlier.

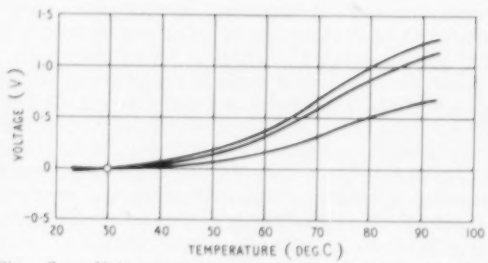

Fig. 2. *Voltage/temperature characteristics of three identical tubes each having a nickel cathode and a 99·6/0·4% helium/argon gas filling.*

represented in each figure are of tubes with identical construction and the same cathode material but different gas fillings. Fig. 1(a) is for tubes with nickel cathodes and (b) for a commercial stabilizer having a cerium-alloy* cathode.

These results show clearly the different running-voltage/temperature characteristics which can be observed in tubes with different cathode materials and different gas fillings.

A word of warning must be added about the spread of the results obtained. In this article only the mean characteristic is given and it should be remembered that the spread of characteristics of

* This alloy is called misch\metal and consists of 45% cerium, 48% iron, 5% of various rare earths and 5% of impurities.

individual tubes of the same type is often very large. This spread is illustrated by Fig. 2 which shows the running-voltage/temperature characteristics of three identical commercial tubes. The characteristics given in the various figures merely show the general shape of the curves and should not be taken as an absolute measure of the running-voltage/temperature coefficient.

(2) *Tubes with Different Cathode Materials*

To determine the influence of the cathode material on the running-voltage/temperature characteristic, a number of tubes with different cathode materials were specially produced. All these tubes were of identical construction. They were of the miniature type with a cylindrical cathode, the anode being a wire at the axis. The different cathode materials used were copper, nickel, molybdenum, zirconium and tantalum. Six tubes of each type were obtained, of which three were filled with a 99·7/0·3% neon/argon mixture and three with a 99·55/0·45% helium/argon mixture.

Since large differences in the initial drifts, as well as different running-voltage/temperature characteristics, have been observed for the tubes, it was thought to be desirable to present curves for the different types. These are given on Figs. 3, 4 and 5.

Fig. 4 shows that tubes with molybdenum, zirconium or tantalum cathodes and neon-gas fillings exhibit a falling running-voltage/temperature characteristic. Furthermore, this characteristic is very nearly a straight line. On the other hand copper and nickel cathodes with neon-gas fillings exhibit a steep rising characteristic. Also the absolute change in the running voltage is much greater in the case of copper and nickel than with the other cathode materials (note the different scale for copper on Fig. 4).

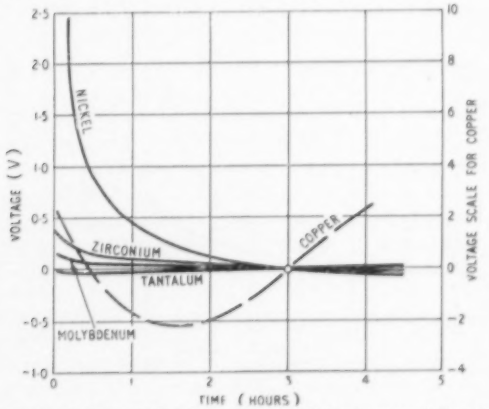

Fig. 3. *Voltage drift of experimental tubes having different cathode materials and neon/argon gas fillings.*

Fig. 3 shows a similar difference for the initial drifts. Tubes with copper and nickel cathodes have an initial drift which is many times that of the other types.

For tubes with helium-gas fillings, the difference between the running-voltage/temperature characteristics of the different types is not so marked. All types of cathodes exhibit a rising running-voltage/temperature characteristic [Fig. 5(b)]. In this case it is only the tubes with copper cathodes which show a much larger change in the running voltage than those with cathodes of other materials.

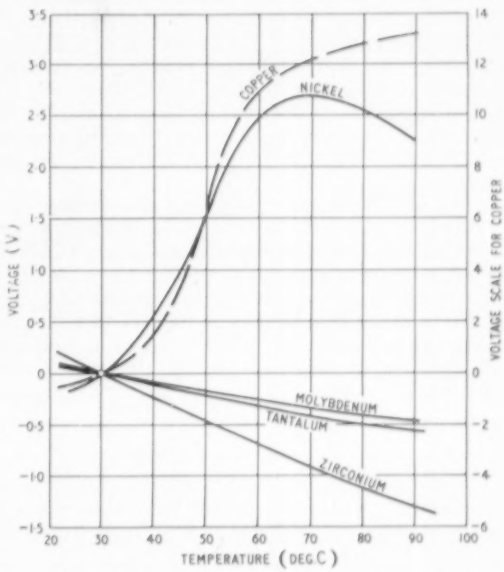

Fig. 4. *Voltage/temperature characteristics of experimental tubes having different cathode materials and neon/argon gas fillings.*

(3) *Tubes with Different Gas Fillings*

The previous tests indicated to what extent the running-voltage/temperature characteristic depends on the gas filling of the tube. It remained to show that a gradual change in the gas filling from pure neon to pure helium would produce a corresponding change in the running-voltage/temperature characteristic.

Measurements were made with two groups of tubes. Group A had cerium-alloy cathodes and gas fillings of 45 mm neon; 30 mm neon + 10 mm helium; 20 mm neon + 20 mm helium; 8 mm neon + 32 mm helium; 40 mm helium. To the pure neon 0·67% argon was added; in all other gas fillings the argon content was 2·5%. Group B had nickel cathodes and fillings of 40 mm neon; 30 mm neon + 10 mm helium;

20 mm neon + 20 mm helium; 10 mm neon + 30 mm helium; 40 mm helium. To each gas filling 0·5% argon was added.

Three to six tubes of each type have been tested and the mean results are represented in Fig. 6.

Tests made on Group A (cerium-alloy cathode) verified the above deductions. Fig. 6(a) shows that the negative temperature coefficient observed for this type decreases when the gas filling is changed from pure neon to helium. The variation of temperature coefficient is not, however, always gradual. There is a large decrease in the temperature coefficient when the gas is changed from pure neon to 30 mm neon + 10 mm helium. This may be due to the difference in argon content in the two gas fillings. For 20 mm neon + 20 mm helium, the temperature coefficient is similar though slightly greater than for 30 mm neon + 10 mm helium. A further increase in the helium percentage results in a positive temperature coefficient. (In this region the change becomes a gradual one.)

For group B (nickel cathode) the results obtained are not well defined. Fig. 6(b) suggests that the positive temperature coefficient which is observed for this group is smaller for a 50/50% neon/helium mixture than for either pure neon or pure helium. However, this may be due to the very large spread of results. The individual characteristics observed for the different types are actually overlapping.

(4) *Tubes with Different Gas Pressures*

Tests to determine the influence of gas pressure on the temperature coefficient have been carried out as a result of reading an Australian patent[10]. This claims that a plot of temperature coefficient against gas pressure gives an S-shaped curve, which cuts the zero axis at a number of points. Furthermore the patent states that the temperature coefficient is proportional to the initial drift.

Measurements were made with tubes having cerium-alloy cathodes and 99·33/0·67% neon/argon gas fillings. Four tubes of each of the pressures 30, 35, 40, 45 and 50 mm of mercury were tested. This type seemed suitable because the observed running voltage/temperature characteristic is very nearly a straight line.

Previous measurements have already shown that, in general, tubes which exhibit a large change in running voltage with change of temperature have also large initial drifts of running voltage. However, it seems most unlikely that the initial drift may generally be taken as an absolute measure of the temperature coefficient. On a considerable number of tubes similar drifts but different running-voltage/temperature characteristics and vice versa have been observed.

Lower and upper limits of the temperature coefficients for different gas pressures are plotted in Fig. 7. The figure shows a considerable spread of results and it can be seen that, from a practical point of view, between 35 mm and 50 mm of mercury, the influence of gas pressure on the temperature coefficient is negligible.

Similar tests were made with tubes having a 97·8/2·2% helium/argon gas filling. The results show that the running-voltage/temperature characteristics obtained for different gas pressures are well within the limits of spread observed for tubes of the same type.

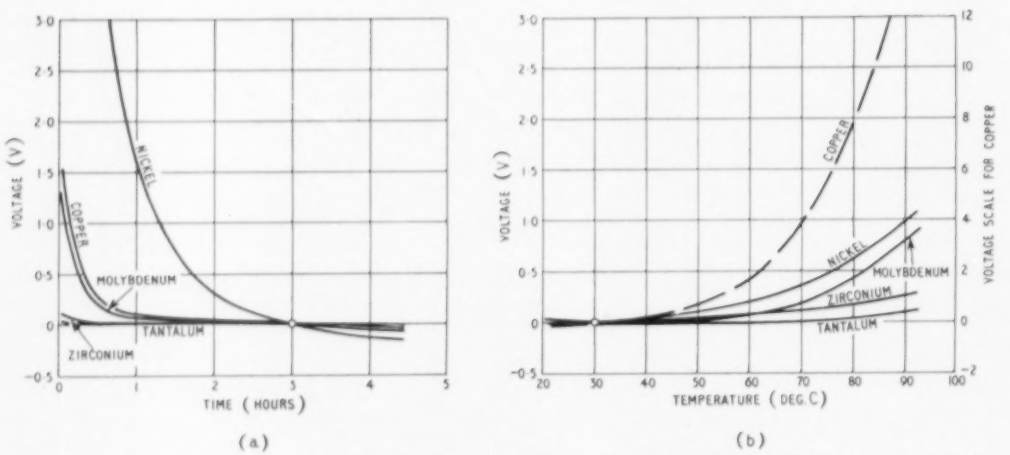

Fig. 5. *Voltage drift (a) and voltage/temperature characteristics (b) of experimental tubes having different cathode materials and helium/argon gas fillings.*

These tests thus do not substantiate the claims made in the Australian patent.

(5) *Tubes with Different Dimensions*

There seemed to be some doubts as to whether the construction of the tube influences its running-voltage/temperature characteristic. Therefore, a number of tubes having different dimensions but identical cathode materials and gas fillings, were tested. Four batches of tubes were obtained, each one having a cylindrical cathode made of cerium-alloy and the anode consisting of a wire at the axis.

Particulars about the approximate dimensions of the different batches are summarized in Table 1.

TABLE 1

Batch No.	Anode Dia. (mm)	Cathode Dia. (mm)	Cathode Length (mm)	Gas Volume (cm^3)
1	1·5	20	36	31·5
2	1·0	20	28·5	42
3	1·0	12·5	21·5	6·9
4	1·0	12·5	19·5	6·9

The gas filling consisted of a 97·8/2·2% helium/argon mixture at a pressure of 40 mm of mercury. All batches had gone through identical production processes.

Fig. 8 shows the running-voltage/temperature characteristics obtained. Only one curve for each type of construction is represented. It will be seen that from a practical point of view the dimensions do not seem to affect the running-voltage/temperature characteristic of the tube.

Discussion of Results

Summarizing, it may be stated that the tests made with various batches of specially designed tubes show that:—

(a) The influence of gas pressure and tube dimensions on the temperature coefficient is negligible.

(b) The running-voltage/temperature characteristic depends on the cathode material and the gas filling of the tube.

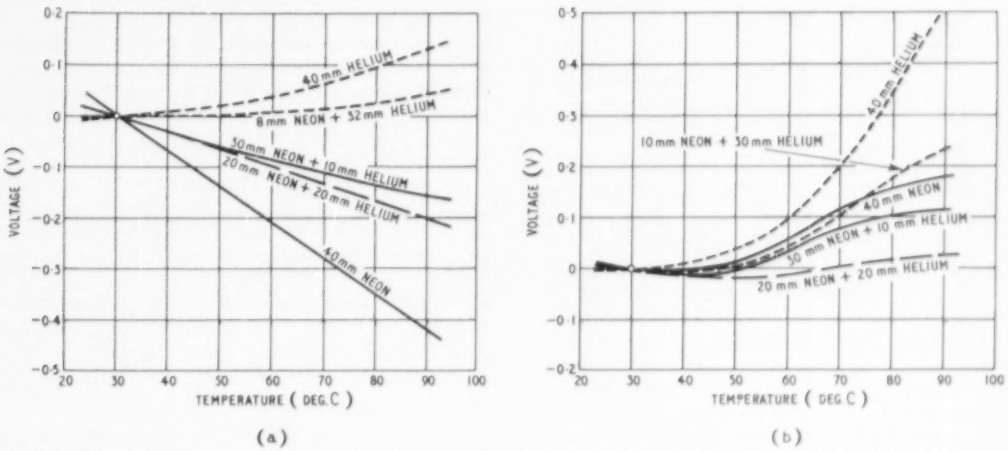
VOLTAGE (V)
TEMPERATURE (DEG.C)
40 mm HELIUM
8 mm NEON + 32 mm HELIUM
30 mm NEON + 10 mm HELIUM
20 mm NEON + 20 mm HELIUM
40 mm NEON
10 mm NEON + 30 mm HELIUM
40 mm NEON + 10 mm HELIUM
20 mm NEON + 20 mm HELIUM
(a)
(b)

Fig. 6. *Voltage/temperature characteristics of cerium-alloy (a) and nickel (b) cathode tubes with different gas fillings.*

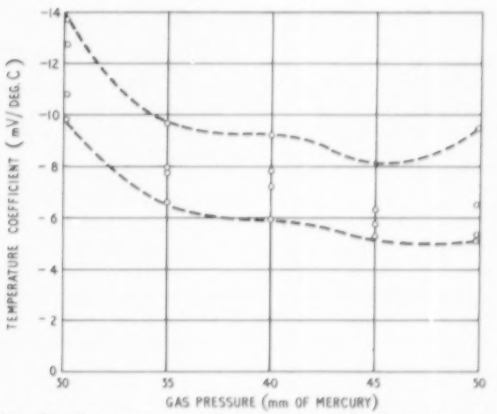

Fig. 7. *Temperature coefficient as function of gas pressure for cerium-alloy cathode tubes having neon/argon gas fillings.*

Positive temperature coefficients have been observed for tubes having copper, nickel, molybdenum, tantalum and zirconium cathodes and helium-gas fillings. Tubes with cerium-alloy, molybdenum, tantalum and zirconium cathodes and neon-gas fillings exhibited negative

coefficients, while those with copper and nickel cathodes showed a steep rising running-voltage/temperature characteristic.

Jurriaanse[11] explained theoretically the variation of running voltage with temperature by considering the change in gas density produced by the temperature. He concluded that a negative coefficient should always be obtained and confirmed this by testing a nickel cathode tube with a 99·5/0·5% helium/argon gas filling.

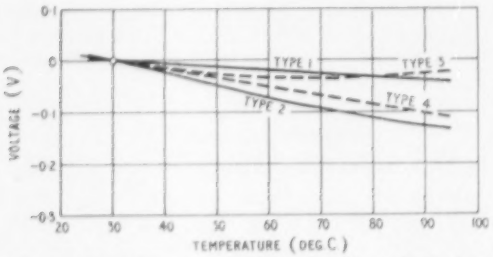

Fig. 8. *Voltage/temperature characteristics of tube types with different dimensions.*

Differences between this theory and the experimental running-voltage/temperature characteristics observed on various types of tubes have been ascribed[8,9] to impurities and/or adsorbed gases. These impurities, released in these tests with rising temperature, produce changes in the gas mixture and in the cathode surface and may, therefore, influence the running voltage considerably.

According to this assumption, the spread of the obtained results is due to small and inevitable differences in the impurities. The similarity between voltage drifts and running-voltage/temperature characteristics can thus be explained, both being due to the same cause.

An interesting observation may be pointed out. A batch of standard stabilizers, with cerium-alloy cathodes and helium/argon gas fillings was tested. A small positive temperature coefficient was obtained. Later on, another batch of these stabilizers was produced. The tubes were exactly the same as those of the previous batch, except that they had undergone a slightly different production process. A very small negative temperature coefficient was observed for this batch.

Nevertheless, there are still some points which are not easily explained satisfactorily. Tests made on tubes with different gas fillings show clearly that the gas influences the temperature coefficient. In many cases positive temperature coefficients have been observed for helium while those for neon were negative. The effect of the gas filling was stated by Jurriaanse[11] to be due to different running-voltage/gas-density curves for neon and helium. However, as pointed out before, the temperature coefficient should be negative in both cases. Benson and Mayo[9] explained the positive temperature coefficients now observed for helium-gas fillings. Since, however, the percentage of impurities is small and similar in neon and helium gases as supplied to valve manufacturers, the completely different characteristics are difficult to explain. Moreover, the various running-voltage/temperature characteristics observed for different batches of tubes can only be ascribed to differences in the effect of the impurities on the different cathode materials. It seems difficult to believe that the extremely large differences observed in the running-voltage/temperature characteristics of, for instance, nickel- and tantalum-cathode tubes can be explained in this way.

It should be noted that the aim of the work described here was to obtain information about the effect, which is likely to be expected in practice, of ambient temperature changes on the running voltage of a glow-discharge stabilizer, having a given cathode material and gas filling. Generalization is, however, difficult because of the considerable spread of running-voltage/temperature characteristics even for nominally identical tubes.

Acknowledgments

The work recorded here has been carried out in the Department of Electrical Engineering at the University of Sheffield. The authors wish to thank Mr. O. I. Butler, M.Sc., M.I.E.E., A.M.I.Mech.E., for facilities afforded in the laboratories of this Department. They also wish to acknowledge the kindness of the English Electric Valve Co. Ltd., in supplying all the special tubes for examination and are grateful to them for helpful discussions and valuable suggestions.

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COMPATIBLE COLOUR-TELEVISION

Part 2—*Comparison of Two Sub-Carrier and N.T.S.C. Systems*

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(Concluded from p. 9, January issue)

SUMMARY.—In this part the two sub-carrier (t.s.c.) system, described in Part 1, is compared with the American N.T.S.C. system. Particular attention is paid to shortcomings of the transmission characteristics, signal-to-noise conditions, crosstalk, sub-carrier annoyance and receiver complexity.

HAVING described the two sub-carrier system in Part 1, it will now be compared with the American N.T.S.C. system, which employs only one sub-carrier.

The N.T.S.C. signal can be written as[21]

$$E_y + E_Q \sin(\omega t + 33^\circ) + E_I \cos(\omega t + 33^\circ)$$

where

$$\begin{aligned} E_y &= \alpha_0 E_G + \beta_0 E_R + \gamma_0 E_B \\ E_Q &= 0{\cdot}41\,(E_B - E_y) + 0{\cdot}48\,(E_R - E_y) \\ E_I &= -0{\cdot}27\,(E_B - E_y) + 0{\cdot}74\,(E_R - E_y) \end{aligned} \quad .. \quad .. \quad .. \quad (1)$$

For rather low colour-difference frequencies the signal can be represented as

$$E_y + K_1\,(E_R - E_y)\cos\omega t + K_2\,(E_B - E_y)\sin\omega t \quad .. \quad .. \quad .. \quad (2)$$

In the receiver the display signals are formed according to

$$\begin{aligned} &(E_R - E_y) + E_y \\ &(E_G - E_y) + E_y \\ &(E_B - E_y) + E_y \end{aligned} \quad .. \quad .. \quad .. \quad (3)$$

where

$$\alpha_0\,(E_G - E_y) = -\beta_0\,(E_R - E_y) - \gamma_0\,(E_B - E_y).$$

The video signal of the system using two sub-carriers (t.s.c. system) can be written as

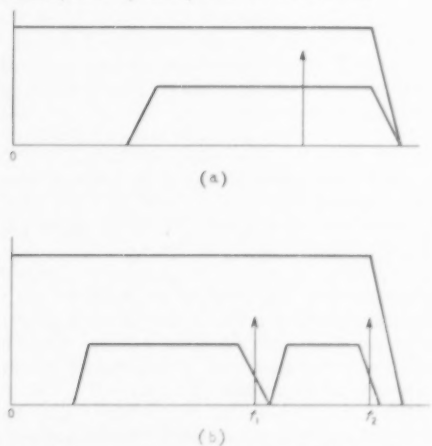


Fig. 5. *Video-frequency spectrum of N.T.S.C. signal (a) and of t.s.c. signal (b).*

$$E_y + x_1 E_R \cos\left(\omega_1 t \pm \frac{\pi}{4}\right) + x_2 E_B \cos\left(\omega_2 t \pm \frac{\pi}{2}\right) \quad .. \quad .. \quad (4)$$

The sub-carriers are supposed to be single-sideband modulated (Fig. 5) for this system produces the best signal-to-noise conditions for the colour signal transmission. (See paragraph: "Signal-to-noise conditions".)

In the receiver, the display signals are formed according to

$$\begin{aligned} &E_R + E_y' \\ &E_B + E_y' \\ &E_G + E_y' \end{aligned} \quad .. \quad .. \quad .. \quad (5)$$

where $\alpha_0 E_G = E_y - \beta_0 E_R - \gamma_0 E_B$ and E_y' denotes the higher frequencies of the luminance signal (mixed highs).

Shortcomings in Luminance Signal Transmission

In the first place we want to discuss the influence of defects in the luminance signal transmission.

In the N.T.S.C. system distortion of the luminance signal will only give rise to a corresponding distortion of picture brightness; the colour hue will be unaffected.

This property can be verified as follows:—

If a distortion Δ is present in the luminance signal, the signal fed to the display will be

$$\begin{aligned} &(E_R - E_y) + E_y + \Delta \\ &(E_B - E_y) + E_y + \Delta \\ &(E_G - E_y) + E_y + \Delta \end{aligned} \quad .. \quad .. \quad .. \quad (6)$$

Because signal components which are the same for all three display guns will deliver a white-light contribution the colour reproduced by (6) can be described as a superposition of the original colour and a white-light component Δ.

In the t.s.c. system, distortion of the luminance signal will affect the hue as well as the brightness in the colour picture (apart from distortion in the 'mixed highs' which, in principle, can have no influence on colour reproduction).

Introducing again a distortion Δ, the display

signals in the t.s.c. receiver will be

$$E_R\,;\ E_B\,;\ E_G + \frac{1}{\alpha_0}\,\Delta \quad .. \quad .. \quad .. \quad (7)$$

So colour as well as brightness will be affected.

It may be asked how the colour signals have to be chosen in order to assure that the hue is not affected.

This can be found by introducing colour signals E_{C1} and E_{C2} of generalized form:

$$\begin{aligned} E_{C1} &= \alpha_1 E_G + \beta_1 E_R + \gamma_1 E_B \\ E_{C2} &= \alpha_2 E_G + \beta_2 E_R + \gamma_2 E_B \end{aligned} \quad .. \quad (8)$$

and determining the expressions for the display signals.

These expressions have to equal

$$\begin{aligned} &E_R + \Delta \\ &E_B + \Delta \\ &E_G + \Delta \end{aligned} \quad .. \quad .. \quad .. \quad (9)$$

It will be found that these conditions are satisfied if

$$\alpha_1 + \beta_1 + \gamma_1 = 0 = \alpha_2 + \beta_2 + \gamma_2 \quad .. \quad (10)$$

Consequently, the colour signals have to be

$$\left.\begin{aligned} E_{C1} &= \alpha_1 E_G + \beta_1 E_R - (\alpha_1 + \beta_1)\, E_B \\ E_{C2} &= \alpha_2 E_G + \beta_2 E_R - (\alpha_2 + \beta_2)\, E_B \end{aligned}\right\} \quad (11)$$

The colour signals of the two sub-carrier system being E_R and E_B and thus different from (11) may be altered but it is not possible to introduce colour signals like (11) because these signals may take negative values. If in $E_C \cos \omega t$ the signal E_C has a negative value the sub-carrier is overmodulated and it is impossible to recover the right signal E_C at the receiver by non-synchronous detection. Though a d.c. component might be added to E_{C1} and E_{C2} in order to prevent negative values, this is not an advisable proposition because the peak value of the sub-carrier in the video signal is increased and a rather large sub-carrier amplitude will be present in dark areas of the picture. On the other hand, freedom from hue distortion, due to luminance signal distortion, is not a very important matter. This is because a luminance signal distortion in the first megacycle of the video signal has itself a serious affect on picture quality and an additional colour error will not make the effect much worse.

Shortcomings of the Sub-Carrier Transmission

As a luminance signal is transmitted, in neither system does the picture brightness depend on the other two transmitted signals. (This principle is known as the 'constant luminance' principle.) Therefore, picture brightness is unaffected by distortion of the sub-carrier's transmission and only the hue and the saturation are altered[22, 23].

Variation of the Relative Sub-Carrier Amplitude

If the ratio between sub-carrier amplitude and the luminance signal level at the demodulators departs from the right value, the N.T.S.C. colour picture shows a fault in colour saturation whereas the colour hue remains correct. This property can be verified in the same way as is done for shortcomings in the luminance signal. In the t.s.c. system, however, a deviation of relative sub-carrier amplitude affects the hue as well as the saturation.

Shortcomings in the amplitude-frequency characteristic of the transmission path may cause the sub-carrier amplitude to be wrong and may occur due to misadjustment of the i.f. amplifier, mistuning or selective fading. As these faults may appear rather frequently, it seems advisable, especially in the t.s.c. system, to prevent a wrong relative sub-carrier amplitude by automatic gain control of the sub-carriers.

As already mentioned in Part 1 for this purpose reference signals, like the burst of the N.T.S.C. signal, can be introduced for the two sub-carriers. If there are two bursts occurring at different times (for example, alternating on successive lines), their amplitudes can possibly be as high as the peak values of the sub-carriers so that these values can easily be obtained by normal peak detection of the red and blue signal. The peak values of the sub-carriers derived in this manner can be compared with the peak value of the luminance signal (for instance, by measuring the sync pulse magnitude) which comparison controls the amplification of the colour channels.

Variation of the Relative Sub-Carrier Phase

In the N.T.S.C. system there may occur a phase error of the sub-carrier arriving at the demodulator with respect to the phase of the synchronized decoding signal. This error in relative sub-carrier phase will affect the hue in the colour picture. According to American publications a deviation of more than 15° seems to be intolerable[24].

In the t.s.c. system the sub-carrier phase is quite unimportant.

A deviation of the relative sub-carrier phase may occur due to

(1) 'differential phase', which means that the phase-frequency characteristic depends on the luminance signal level[25].

(2) sensitivity of decoding phase to burst amplitude variations which is present in many local sub-carrier oscillators.

In the latter case indirectly the sub-carrier phase, and so the hue, is affected by imperfections in the amplitude characteristic of the transmission path though in principle in the N.T.S.C.

system the hue is independent of sub-carrier amplitude.

Mutual Cross-Talk

Cross-talk between the three transmitted signals may occur due to faults in the transmission characteristics.

(a) In both systems the sub-carrier amplitudes will depend on the luminance signal level if the transmission path shows some non-linearity (differential gain). So a component proportional to $E_y.E_c$ will then be present in the colour channels.

(b) In the N.T.S.C. system mutual cross-talk of the colour signals will occur if the amplitude characteristic is not flat and if the phase characteristic is curved[26].

In the t.s.c. system these distortions do not cause any cross-talk.

(c) In both systems, due to vestigial-sideband transmission of the r.f. vision carrier, the sub-carrier amplitude will depend on the luminance signal level and the latter on the sub-carrier amplitude. However, these imperfections turn out to be rather unimportant. Also, in the compatible picture of both systems, contrast deterioration is not noticeable[25].

(d) In both systems a beat may occur between the sound and vision carriers especially when the vision-carrier detector is non-linear. Experimentally, the t.s.c. system turns out to be somewhat less sensitive to this effect than the N.T.S.C. system[27].

Apart from these shortcomings in the signals, of course, imperfections in the amplitude and phase characteristic deteriorate the transient responses of these signals, just as they do in black and white television.

Lastly, we should mention that for both systems a variation in the overall phase characteristic affects the time coincidence of the luminance and colour signals[28].

Signal-to-Noise Conditions

In order to compare the two systems, the following situation is supposed to exist after the second detector in the receiver.

(1) The peak values of E_y, E_R, E_B and E_G are unity.

(2) In both the N.T.S.C. and t.s.c. receivers the two colour signals have the same bandwidth. In both receivers the bandwidths are f_c cycles per second.

(3) In the N.T.S.C. receiver the signals E_{R-y} and E_{B-y} are detected.

The noise added to the video signal has a uniform energy distribution over the whole band and the r.m.s. value is U_N per $2f_c$ cycles.

The signal-to-noise ratio after demodulation of a double-sideband modulated sub-carrier $E_R \cos \omega t$ whose colour signal E_R has a bandwidth f_c and a peak value E_{Cmax} will be

$$\frac{E_{Cmax}}{U_N}$$

If, however, the received sub-carrier is single-sideband modulated, the bandpass filter of the detector may be $(1 + \delta)\ f_c$ instead of $2f_c$. See Fig. 6.

Therefore, for equal peak values and modulation depths of the received sub-carriers the single-sideband modulation delivers a better signal-to-noise ratio, being

$$\frac{E_{Cmax}}{U_N} \frac{\sqrt{2}}{\sqrt{1+\delta}}$$

In the N.T.S.C. system, no single-sideband modulation of the sub-carrier can be applied, because mutual-cross-talk of the recovered colour signals will occur if only one sideband is present.

If each colour signal is modulated on a separate sub-carrier, single-sideband modulation is possible. The noise component in the luminance signal is only considered for the band 0–f_c because above the frequency f_c the conditions in both systems are the same (only luminance information is transmitted). The r.m.s. value of this luminance noise component is $U_N/\sqrt{2}$.

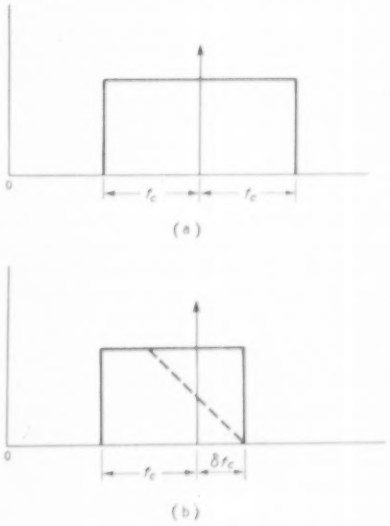


Fig. 6. *Bandpass filter in receiver for sub-carrier with double-sideband modulation (a) and single-sideband modulation (b).*

Denoting the noise components in the luminance signal and in the colour signals by N_y, N_{R-y},

N_{B-y}, N_R and N_B respectively, the three signals available in the N.T.S.C. receiver can be written as

$$E_y + N_y;\ K_1(E_R - E_y) + N_{R-y};$$
$$K_2(E_B - E_y) + N_{B-y}$$

and in the two sub-carrier system receiver as

$$E_y + N_y;\ x_1 E_R + N_R;\ x_2 E_B + N_B$$

The r.m.s. value of N_y is $U_N/\sqrt{2}$.

The r.m.s. values of N_{R-y} and N_{B-y} are both U_N, whereas for N_R and N_B this value equals

$$\tau U_N \text{ where } \tau = \sqrt{\frac{1+\delta}{2}}$$

due to the single-sideband modulation in the two sub-carrier system.

In the N.T.S.C receiver the output signals acting on the guns of the display unit are formed according to

$$(E_R - E_y) + E_y$$
$$(E_B - E_y) + E_y$$
$$(E_G - E_y) + E_y$$

The signal $E_G - E_y$ is obtained by matrixing:

$$z_0(E_G - E_y) = -\beta_0(E_R - E_y) - \gamma_0(E_B - E_y)$$

So a noise component

$$-\frac{\beta_0}{z_0 K_1} N_{R-y} - \frac{\gamma_0}{z_0 K_2} (N_{B-y})$$

will be present in this signal.

The three signals fed to the display are:

$$(E_R - E_y) + E_y + N_y + \frac{1}{K_1} N_{R-y}$$
$$(E_B - E_y) + E_y + N_y + \frac{1}{K_2} N_{B-y}$$
$$(E_G - E_y) + E_y + N_y - \frac{\beta_0}{z_0 K_1} N_{R-y}$$
$$- \frac{\gamma_0}{z_0 K_2} N_{B-y} \quad .. \quad .. \quad .. \qquad (12)$$

In the two sub-carrier system the red and blue signals are delivered directly by the demodulators whereas the green signal is obtained by matrixing according to

$$z_0 E_G = E_y - \beta_0 E_R - \gamma_0 E_B$$

It contains a noise component

$$N_y - \frac{\beta_0}{x_1} N_R - \frac{\gamma_0}{x_2} N_B$$

So the three signals fed to the display are (neglecting the mixed highs)

$$E_R + \frac{\tau}{x_1} N_R$$
$$E_B + \frac{\tau}{x_2} N_B$$
$$E_G + \frac{1}{z_0} N_y - \frac{\beta_0 \tau}{x_1 z_0} N_R - \frac{\gamma_0 \tau}{x_2 z_0} N_B \quad .. \qquad (13)$$

In order to compare the noise levels in both systems, the values of z_0, β_0, γ_0, K_1, K_2, x_1, x_2 and τ have to be known. z_0, β_0 and γ_0 are determined by the sensitivity of the human eye for the three primary colours. In the N.T.S.C. system these constants are

$$z_0 = 0{\cdot}59 \qquad \beta_0 = 0{\cdot}3 \qquad \gamma_0 = 0{\cdot}11$$

K_1 and K_2 are also known from N.T.S.C. system specification and are

$$K_1 = \frac{1}{1{\cdot}14}, \qquad K_2 = \frac{1}{1{\cdot}14 \times 1{\cdot}78}$$

The constants x_1 and x_2 will be chosen in such a way that, as well as the relative peak values of the combined sub-carriers, the ratios of the three noise contributions in the three channels are nearly equivalent in both systems.

In this way the values

$$x_1 = 0{\cdot}41, \qquad x_2 = 0{\cdot}23$$

are obtained.

The constant $\tau = \sqrt{\frac{1+\delta}{2}}$ is supposed to be 0·8 ($\delta = 0{\cdot}25$).

Substituting all these values in (12) and (13) gives the following r.m.s. values for the noise in the three colour channels at the receiver.

	N.T.S.C.	T.S.C.
green	$0{\cdot}99\ U_N$	$1{\cdot}65\ U_N$
red	$1{\cdot}34\ U_N$	$1{\cdot}96\ U_N$
blue	$2{\cdot}16\ U_N$	$3{\cdot}50\ U_N$

So in the two sub-carrier system the signal-to-noise ratio in all channels is somewhat lower than in the N.T.S.C. system.

However, this difference in signal-to-noise values is not equivalent to an equal decrease in signal-to-noise ratio in black-and-white television. The visual effect of the three noise components together depends on their combined action in the colour picture. For instance, it will make a great difference in picture appreciation if this concerted action leads to luminance fluctuations only or to fluctuations in hue only.

The result of the superposition of the three noise components is determined by their mutual correlation. If this correlation is different in two colour transmissions the noise figures cannot be compared directly.

In the N.T.S.C. system the correlation and its visual consequences can be easily understood.

The noise components are

$$\text{Red} \quad N_y + \frac{1}{K_1} N_{R-y}$$

$$\text{Blue} \quad N_y + \frac{1}{K_2} N_{B-y}$$

$$\text{Green} \quad N_y - \frac{\beta_0}{z_0 K_1} N_{R-y} - \frac{\gamma_0}{z_0 K_2} N_{B-y}.$$

The three noise contributions N_y give rise to fluctuations which do not affect the hue because equal signals in the three display channels represent a black-and-white picture. The other noise components give rise to fluctuations which do not affect the luminance due to the constant luminance principle. So the noise can be easily split into a 'luminance noise' and 'colour noise'.

In the t.s.c. system this discrimination is not so obvious, nevertheless, in this system also the noise can be split into a luminance and a colour part.

The noise components in the t.s.c. system are

$$\text{Red} \quad \frac{\tau}{x_1} N_R$$

$$\text{Blue} \quad \frac{\tau}{x_2} N_B$$

$$\text{Green} \quad \frac{1}{z_0} N_y - \frac{\beta_0 \tau}{x_1 z_0} N_R - \frac{\gamma_0 \tau}{x_2 z_0} N_B$$

Due to the constant luminance the components $\frac{\tau}{x_1} N_R$, $\frac{\tau}{x_2} N_B$ and $-\frac{\beta_0 \tau}{x_1 z_0} N_R - \frac{\gamma_0 \tau}{x_2 z_0} N_B$ together do not affect the luminance.

The remaining component $\frac{1}{z_0} N_y$ in the green signal affects luminance as well as hue. However, we can add $N_y - N_y$ to the noise in the red and blue channels so writing the noise components as

$$\text{Red} \quad N_y + \frac{\tau}{x_1} N_R - N_y$$

$$\text{Blue} \quad N_y + \frac{\tau}{x_2} N_B - N_y$$

$$\text{Green} \; N_y - \frac{\beta_0 \tau}{x_1 z_0} N_R - \frac{\gamma_0 \tau}{x_2 z_0} N_B + \left(1 - \frac{1}{z_0}\right) N_y$$

Now the components $-N_y$, $-N_y$ and

$$\left(1 - \frac{1}{z_0}\right) N_y$$

represent a colour noise component as the luminance effect in red, blue and green is proportional to β_0, γ_0 and z_0 and therefore the combined luminance effect is

$$-\beta_0 N_y - \gamma_0 N_y + (z_0 - 1) N_y = 0$$
$$(z_0 + \beta_0 + \gamma_0 = 1)$$

In this way we can also in the t.s.c. system separate colour noise from luminance noise.

Again comparing both systems, we see that there is only a difference in colour noise. This will be clear because, due to the constant luminance principle, the luminance can only be affected by the luminance signal itself.

Based on the values of the coefficients given above the colour noise components are found to be

	N.T.S.C.	T.S.C.
Red	1·14	$2{\cdot}08 = 1{\cdot}83 \times 1{\cdot}14$
Blue	2·04	$3{\cdot}56 = 1{\cdot}74 \times 2{\cdot}04$
Green	0·7	$1{\cdot}25 = 1{\cdot}84 \times 0{\cdot}7$

So in the t.s.c. system the colour noise is about 1·8 times as much as in the N.T.S.C. system.

This difference in signal to colour noise conditions is due to the fact that in the N.T.S.C. system synchronized detection is used and therefore the sub-carrier can be transmitted with a minimum peak value. Moreover the amplitudes of the two sub-carriers $E_R \cos \omega_1 t$ and $E_B \cos \omega_2 t$ add linearly whereas the amplitudes of the components $(E_R - E_y) \cos \omega t$ and $(E_B - E_y) \sin \omega t$ add quadratically.

Up to this point the comparison of noise contributions has been based on the supposition that in both systems both colour signals have the same bandwidths. This is not quite correct, however, because in the N.T.S.C. system the I-signal bandwidth is about twice as large as the Q-signal bandwidth. However, if the unequal bandwidths are taken into account and a similar situation is supposed to exist in the t.s.c. system the ratio of noise contributions in both systems is almost the same as found above.

Of course, the effect of increased colour noise on picture quality depends on the relative importance of colour noise with respect to brightness noise. In an article called "A Subjective Study of Colour Synchronization Performance" by Burgett[29] some measurements are described which have been carried out in order to determine the sensitivity of colour picture-quality in the N.T.S.C. system for noise added to the synchronizing and information signals present in the receiver. It turned out that the ratio between the signal-to-noise ratios in luminance and colour channels, might be decreased two or three times (7 to 10 dB) before the annoyance value of brightness noise is equivalent to that produced by colour noise.

It follows from this that the visual-effect of the higher colour noise level in the two sub-carrier system certainly affects picture quality less than an equivalent increase of noise level in monochrome television.

We conclude therefore that the signal-to-noise ratio in the colour is worse in the t.s.c. system by a factor around 1·8 but that this disadvantage can be tolerated as it does not increase the signal-to-noise requirements in a transmission path above those needed for black-and-white transmission.

Apart from the random noise, there is the interference due to cross-talk between signal components, caused by incomplete separation of the three signal spectra. This interference has a visual effect similar to random noise because these components vary in phase and cancel out in successive lines, frames and pictures. (See Part 1.)

In the first place there is an interference in the colour signals caused by the luminance signal

components present in the frequency range of the sub-carriers.

To some extent this interference has the same character as colour noise; it only affects picture colour. Similar calculations to those given for colour noise show that its relative value will be about 1·65 times as large in the two sub-carrier system as in the N.T.S.C. system. It is somewhat more for the lower sub-carrier, somewhat less for the higher sub-carrier because the luminance

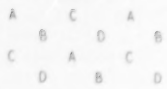


Fig. 7. *Pattern of mutual cross-talk of colour signals in t.s.c. system.*

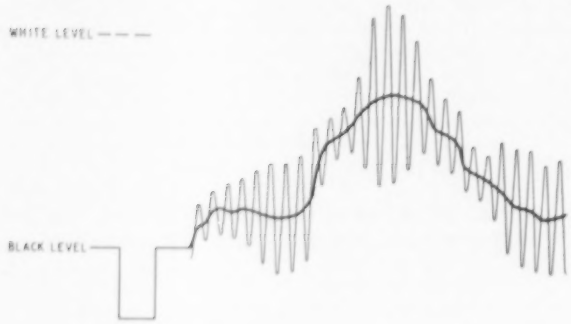


Fig. 8 (above). *"Overswing" of sub-carrier beyond the white and black levels.*

Fig. 9 (right). *Maximum "overswing" in N.T.S.C. system (a) and in t.s.c. system (b).*

components decrease with increasing frequency. However, the visual effect of this interference is less important and usually hardly perceptible.

In the second place, in the t.s.c. system, mutual cross-talk can occur between colour signals if the separating bandpass filters do not cut off sharply enough and pass some sideband components of the undesired sub-carrier. Interference will occur in the picture details and picture contours, showing the pattern of Fig. 7. However, this interference is usually barely visible.

Sub-Carrier Annoyance

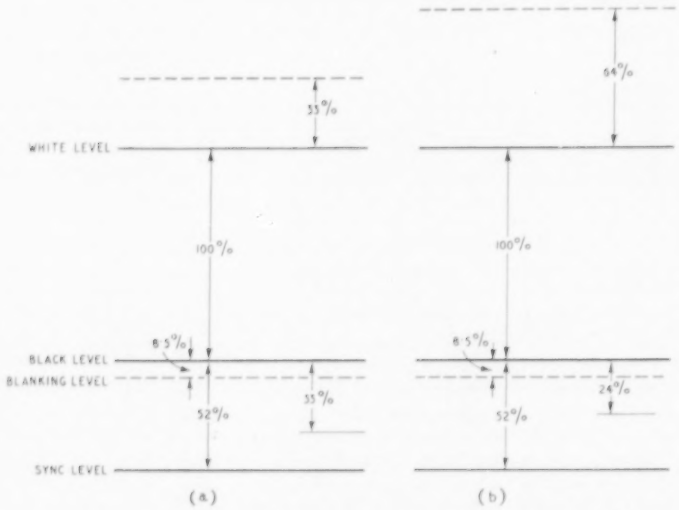
We now wish to draw attention to the annoying effects caused by the presence of sub-carrier in the video signal of the colour-television transmission system.

As mentioned before, the video signal of the two sub-carrier system under discussion contains an amount of sub-carrier equivalent to that in the N.T.S.C. signal. The peak value of the combined sub-carriers is 64% of the luminance signal peak value.

However, this peak value will appear under circumstances which are very different in the two systems. In the N.T.S.C. signal, the sub-carrier amplitude is large if colour is highly saturated. The peak value is reached for primary colours. In the two sub-carrier system, large values of sub-carrier amplitudes occur if the red and blue components are large.

The annoying effects of the sub-carrier(s) in the video signal are of two kinds.

First, the sub-carrier may reach beyond the black and white levels of the luminance signal, as in Fig. 8. If sub-carrier is present in the sync area the line synchronization may be affected and the cancellation of the visual effect of the sub-carrier in black and white reception will be poor. If the sub-carrier reaches above white level the picture carrier may be over-modulated.



In the N.T.S.C. system the overswing beyond black level is 33% and happens if E_G has maximum value and E_B and E_R are zero. The overswing beyond white level is also 33% and happens if E_G is zero and E_B and E_R have maximum value. See Fig. 9.

In the two sub-carrier system, the maximum amount of overswing beyond black level is 24% if

E_G is zero and E_B and E_R have maximum values.

Beyond white level the overswing is 64% if E_G, E_B and E_R have maximum amplitude.

Secondly, the visual effect of sub-carrier in the picture of an existing black-and-white receiver has to be considered.

In order to have some information about this matter, experiments were carried out to determine the relation between viewing distance at which the sub-carrier becomes imperceptible and relative sub-carrier amplitude.

Naturally, these measurements are rather subjective and show large spread. However, it was possible to ascertain that:

(1) the viewing distance at which a sub-carrier is just invisible is practically independent of picture brightness, if the relative sub-carrier amplitude is maintained constant.

(2) the curve representing the increase of critical distance with increasing relative sub-carrier amplitude shows the form indicated in Fig. 10.

(3) if the N.T.S.C. sub-carrier has a frequency equal to the lower sub-carrier frequency of the t.s.c. system there is only a slight difference between the perceptibility of the single N.T.S.C. sub-carrier and the combination of two sub-carriers. The pattern of the N.T.S.C. sub-carrier appears to be finer than the combination pattern of the two sub-carriers, but the effect of this on visibility is more or less cancelled by the more striking stroboscopic effects in the N.T.S.C. pattern.

Of course, these experimental results give only a small amount of information for comparing the two systems. The annoyance to the observer depends on the mean sub-carrier amount during the transmission, which depends on the mean value of hue, saturation and brightness. In the N.T.S.C. system, unsaturated colours give rise to a low sub-carrier level. In the two sub-carrier system, sub-carrier amplitude is small for colours with large green and small red and blue light components.

In our opinion rather extensive experiments are needed to determine the superiority of one system over the other in this respect.

Colour Receiver Circuitry

Another aspect which needs discussion is the construction of the colour receiver.

It will be plain that, whereas the r.f., i.f. and colour-display circuitry of both systems will show only slight differences in principle, the video circuit of the two sub-carrier system will be much simpler than that of the N.T.S.C. system. Though it is rather difficult to give to this quality a figure of merit we can get an impression by considering the number of valve functions which have to be added to the normal black-and-white receiver[30].

In the N.T.S.C. system the following valve functions are needed:

Separation of sub-carrier from video signal	1
Demodulation of sub-carrier	2
Video amplification	3
Burst gating and amplification	1
Sub-carrier oscillator	1
Sub-carrier frequency control	1
Sub-carrier amplification	1
Total	10

In the two sub-carrier system:

Separation of sub-carriers from video signal	1
Double detection (only applied to the lower sub-carrier)	1
Video amplification	3
Total	5

The detection of the sub-carriers is obtained by simple germanium diodes.

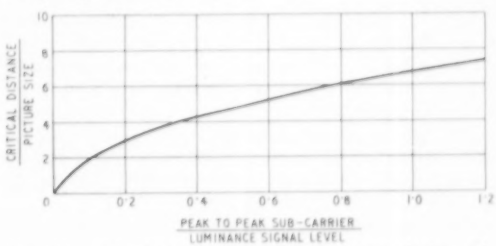


Fig. 10. *Visibility of sub-carrier versus relative sub-carrier amplitude.*

It will be noted that the valve functions mentioned for the two sub-carrier system are all of simple and conventional type. The N.T.S.C. system, however, involves rather complicated valve functions unknown in normal receiver technique; such as, synchronized detection, sub-carrier oscillator and sub-carrier frequency control.

For both systems, only the most essential valve functions have been mentioned. At this point it should be noted that in principle the N.T.S.C. receiver circuitry, without any modification or addition, is suitable for black-and-white reception whereas the two sub-carrier system receiver will reproduce the black-and-white transmission as a green picture if no special measures are taken. However, due to the disturbing effect of luminance signal components passing through the colour channels it seems to be desirable to provide a N.T.S.C. receiver with a so-called 'colour killer',

cutting off the colour channels if no sub-carrier is present. So the difference between the two receivers for black-and-white reception is of minor importance because, after all, special circuitry has to be added in both receivers in order to assure good compatibility with black-and-white transmission.

The regular functioning and the sensitivity to misadjustment are also important properties of the colour receiver.

The two sub-carrier receiver will be rather sensitive to mistuning if no automatic gain control is applied, because the relative sub-carrier amplitude will be wrong.

As mentioned before, in principle a wrong sub-carrier amplitude transmission in the N.T.S.C. system only affects colour saturation, but the hue can also be disturbed if phase of decoding depends on burst-amplitude.

On the other hand, the N.T.S.C. transmission is more sensitive to phase errors in the frequency characteristic of the transmission channel. Further, a third synchronization is needed with a rather critical phase adjustment in the synchronized detection.

Finally, it must be mentioned that the two sub-carrier system may be locked to the mains whereas the N.T.S.C. system has to be free running because the sub-carrier frequency must be constant within about 0·005%.

The comparison of the various aspects of the colour transmission systems is summarized in Table 1.

It is not the intention of the authors to draw any conclusion about the choice of system from this comparison. It can give only a provisional idea about the merits of the systems until extensive comparative experiments have been carried out. Several properties of a practical system are not fully known, so that during experiments certain aspects of colour transmission not mentioned here may turn out to be very important to the choice of the system.

TABLE 1

	N.T.S.C.	T.S.C.
Colour-picture:		
Colour reproduction	=	=
signal-to-noise { luminance noise	=	=
signal-to-noise { colour noise	1	1-80
Monochrome picture:		
sub-carrier annoyance { critical distance	=	=
sub-carrier annoyance { pattern	stroboscopic effects	more coarse
mean sub-carrier amplitude	?	?
Transmission:		
luminance signal wrong	luminance wrong	luminance } wrong hue }
sub-carrier amplitude wrong	constant luminance saturation wrong	constant luminance hue wrong
sub-carrier phase wrong	hue wrong	—
wrong phase or amplitude characteristic	cross-talk	no cross-talk
overswing	white: 33% black: 33%	white: 64% black: 24%
Locked to the mains	not possible	possible
Receiver; extra number of valve functions	10 rather complicated circuitry	5 simple circuitry

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ARRIVAL ANGLE OF H.F. WAVES

Improved Method of Measuring Waves Reflected from the Ionosphere

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(Official communication from D.S.I.R. Radio Research Station, Slough)

SUMMARY.—Apparatus is described for measuring the angle of elevation of h.f. waves arriving at the ground after transmission by way of the ionosphere. The system involves the comparison of the amplitudes of the signals received by two vertically-spaced horizontal loop aerials at heights above the ground of about 33 metres and 12·5 metres. The comparison is effected by amplifying the signal e.m.fs in a twin-channel receiver and applying the i.f. voltages to the deflecting plates of a cathode-ray oscilloscope. It is shown that, if a single ray is incident on the system, the e.m.fs produced in the two aerials are in phase irrespective of their height above ground, so that the corresponding oscilloscope pattern is a straight line, the slope of which is a simple function of the angle of elevation of the ray.

Calibrations of the system over the band 10–20 Mc/s have shown that its behaviour is very close to that expected from the simple theory and that there is no noteworthy change in the calibration with azimuth.

Methods of observation for the general case of the arriving signal consisting of more than one ray are considered.

1. Introduction

In an earlier paper[1] one of the present authors described a method of measuring the angle of elevation at the ground of h.f. signals received after reflection from the ionosphere. This method had been developed with the object of providing data to facilitate the design of aerial arrays for reception of transatlantic telephone signals and, for this purpose, it proved very satisfactory.

It recently became necessary to set up equipment for measuring angles of elevation in connection with the general study of the characteristics of h.f. signals received from long distances; there has also been a revival of interest by the radio engineer in the angles of elevation on certain important radio circuits.

Because of the necessity in both these requirements of making measurements on signals arriving from stations situated in different parts of the world, it was not considered satisfactory to use the method described in reference 1, which involved the measurement of the phase difference of the e.m.fs produced by the signals in two parallel, fixed, horizontal aerials spaced horizontally at equal heights above the ground. This method is most accurate for waves arriving from directions normal to each aerial but the accuracy falls to zero at right angles to these directions.

In order to overcome this weakness, attempts were made to use a similar system in which portable vertical loop aerials, set up at ground level, were substituted for the fixed horizontal aerials previously used. This system was found, however, to suffer severely from site errors presumably caused by re-radiation from trees and other local objects and it was, moreover, found to be a lengthy undertaking to set up the loops and line-up aerial with the necessary accuracy in new positions.

Other methods were therefore considered and, of these, the only ones which appeared to be able to satisfy the requirements were those depending on the comparison of the signal e.m.fs produced in two aerials whose vertical radiation patterns are different. Such methods have been reported by Friis, Feldman and Sharpless[2] and by Kusunose and Namba[3].

One of the systems described in reference 2 consisted of two horizontal dipoles situated at heights above the ground of one-quarter wavelength and one wavelength respectively and connected separately to receivers, the outputs from which operated pen-writing recorders. At the beginning of an observation the two aerials were placed at the same height above ground level and the readings of the recorders equalized. The angle of elevation of the downcoming waves was subsequently determined from the ratio of the recorder deflections obtained when the aerials were at their operating heights.

In the method of Kusunose and Namba, two horizontal aerials at heights $(h + d)$ and $(h - d)$ are connected in parallel and the amplitude (E_1) of the resultant signal e.m.f. is compared with that (E_2) generated in a single horizontal aerial at height h. Assuming that there is no mutual coupling between the aerials and that both aerials are matched into equal load impedances, the ratio (R_A) of the e.m.fs produced by the two aerials is given by:—

$$R_A = \frac{\sqrt{2}\,E_1}{E_2} = \sqrt{2}\cos\left(\frac{2\pi d}{\lambda}\sin\alpha\right)$$

where λ = wavelength and α = angle of elevation.

Similarly the ratio (R_B) of the e.m.fs E_3 and E_4 generated in two single horizontal aerials at

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heights $2d$ and d respectively is given by:—

$$R_B = \frac{E_3}{E_4} = 2\cos\left(\frac{2\pi d}{\lambda}\sin\alpha\right)$$

Since $\frac{dR_B}{d\alpha} = \sqrt{2}\frac{dR_A}{d\alpha}$, the Japanese system described is the less sensitive to changes in α. To obtain the same sensitivity for both systems, it would be necessary to increase the spacing of the two-element array used by Kusunose and Namba. Since this would entail using a higher mast, the simpler method of merely comparing the e.m.fs on single aerials appears to be preferable.

Kusunose and Namba compared the sum and difference of the two e.m.fs instead of comparing them directly. This makes the system much more sensitive to changes in angle of elevation; however, this advantage is a real one only if it is possible to guarantee a corresponding increase in the precision of the line-up procedure and in the stability of the receivers, particularly in the sum-and-difference unit. On balance, the additional complication of the sum-and-difference technique did not appear to be fully justified for the present application and it was decided simply to compare the two voltages directly.

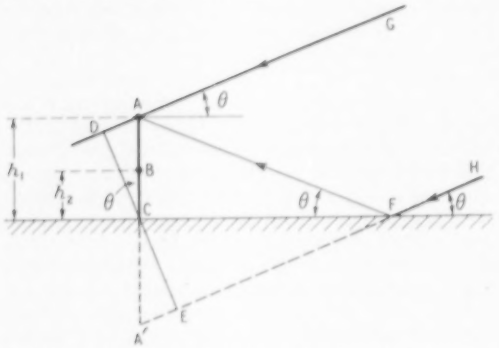

Fig. 1. *Illustrating principle of angle of elevation measuring system.*

In 1936 one of the present authors suggested the use of the method involving the comparison of the e.m.fs produced in two horizontal aerials at different heights above the ground as a means of determining the angle of elevation of aircraft by radar. It was pointed out that an important feature of such a system when the upper aerial is vertically above the lower is that the aerial e.m.fs are in phase for signals at any angle of elevation provided the ground surrounding the system can be regarded as of perfect conductivity and is flat over a sufficiently large area. Such a property is of practical value as it permits the e.m.f. comparison to be made either by goniometer or by using twin-channel receiver technique with cathode-ray oscilloscope display. Radar elevation-measuring systems using goniometer comparison were developed by the authors and used on a large scale during the late war and have been described by Ratcliffe[4]. The height of the masts (73 metres) used in one of those radar systems was such that angles of elevation on suitable sites could be measured down to 1·5° to 2° on a working frequency of about 22 Mc/s and to 0·75° on 50 Mc/s.

Although it was impracticable to construct a system with comparable characteristics for the present purpose on acccunt of mast-height limitations, the calculated performance of a system employing 30-metre masts for measurement on frequencies of about 15 Mc/s upwards was promising enough to warrant its construction.

2. Theory of the System

In Fig. 1, A represents a horizontal aerial at height h_1 above ground. It will be assumed that the source of the radiation arriving at the aerial is so far away that the incident rays may be considered to be parallel. Two rays will arrive at A, namely, the direct ray GA at angle of elevation θ, and a ray reflected at the ground, HFA. If HF be continued to A′ and DCE be drawn at right angles to GD and FA′ then $AD = A'E = h_1 \sin\theta$. This is equivalent to a phase change of $\frac{2\pi h_1 \sin\theta}{\lambda}$ which would represent the phase angle by which the direct ray would lead and the reflected ray lag on the phase of a ray arriving at C assuming no phase change on reflection at the ground.

If it may be assumed that the ground is of high conductivity, the reflection coefficient for horizontally-polarized radiation will be substantially unity and the phase change at reflection will be about 180° for the range of θ with which we are concerned (up to 30° and for frequencies of about 10–30 Mc/s). If, therefore, the electric field of the direct ray at C be represented by $e = E\sin\omega t$, the field at A will be

$$e_A = E\sin\left(\omega t + \frac{2\pi h_1 \sin\theta}{\lambda}\right) + E\sin\left(\omega t - \frac{2\pi h_1 \sin\theta}{\lambda} - \pi\right)$$
$$= 2E\sin\left(\frac{2\pi h_1 \sin\theta}{\lambda}\right)\cos\omega t$$

Similarly for another aerial, B, at height h_2

$$e_B = 2E\sin\left(\frac{2\pi h_2 \sin\theta}{\lambda}\right)\cos\omega t$$

Thus, as already pointed out, the phase of the resultant field is independent of the height of the aerial.

3. Description of the Practical System

In view of the requirement for efficient working on signals arriving from any azimuth, it was considered desirable to use horizontal loops rather than dipoles as the signal pick-up elements. Mechanical difficulties would have been experienced in rotating dipoles into the direction normal to the plane of incidence to give maximum pick-up and to eliminate pick-up from vertically-polarized components of the field.

As pointed out by Ross[5] and elaborated by Horner[6], a loop aerial whose perimeter is not small compared with the operating wavelength, and which therefore carries a non-uniform current, may be regarded as consisting of a uniform-current loop or a magnetic dipole, and an electric dipole. In the present case it was decided to support the loop aerials on a guyed, timber lattice mast the cross-section of which limited the dimensions of the loops used to 1 metre square. For such loops Horner shows that the moment of the magnetic dipole is only about 40% greater than that of the electric dipole and that the electric dipole is parallel to the side of the loop containing the terminals.

In the general case of an angle of elevation system consisting of two such square loops one above the other, the horizontal electric field in the downcoming wave will produce in-phase e.m.fs in them of differing amplitudes. The electric field in the plane of incidence will, however, produce e.m.fs in the electric dipoles which differ in both amplitude and in phase from those produced in the magnetic dipole by the horizontal field unless the electric dipole is normal to the plane of incidence, in which case they will receive no signal. Such effects would be likely to affect the accuracy of the measurements except at the smallest angles of elevation where the component of 'vertical' field along the electric dipole would be small. To overcome this difficulty it was arranged to rotate the loops about a vertical axis so as to orientate the electric dipole in a direction normal to the plane of propagation of the signal to be measured and thus to eliminate the pick-up due to components of field other than the horizontal electric field.

The aerial system consists of two horizontal, single turn, screened loops at heights above ground of 32·6 metres and 12·6 metres respectively. Each loop is capable of rotation about a vertical axis and is driven by an electric motor controlled from the ground; the orientation of the loop is indicated to the operator by means of electrical repeating devices.

Each loop is connected separately to the receiving equipment by twin lead-sheathed transmission lines of equal length; these lines, the cables supplying power to the motors, and the wiring from the repeating apparatus are strapped together and run vertically downwards through the centre of the loops to obviate the induction of unwanted e.m.fs into the loops by currents on the various cables.

The e.m.fs of the two loops are amplified separately in superheterodyne receivers with a common beat oscillator; the characteristics of the receivers can be made identical stage by stage. If, then, equal co-phasal e.m.fs are generated in the loops which, with their associated transmission lines, are identical, the receiver i.f. outputs will also be equal and co-phasal. Consequently if the orthogonal deflecting plates of a cathode-ray oscilloscope are connected to the i.f. output terminals of the receivers, a straight line at 45° to the axes of deflection will be produced. In the case of a single ray incident on the aerial system, the pattern on the oscilloscope will be a straight line the inclination of which is a function of the angle of elevation of the incident ray.

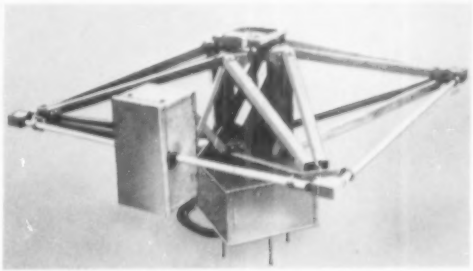

Fig. 2. *View of receiving and lining-up loops above turning-motor housing.*

To check the equality of characteristics of the receiving-loop–transmission-line systems and receivers, small line-up aerials are installed above each receiving loop. These consist of single-turn, screened loops each 10 cm square and they are arranged with their planes parallel to and 10 cm above those of their associated receiving loops (Fig. 2). The two loops are supplied with current at the signal frequency by a coaxial transmission-line system arranged as shown in Fig. 3; the current flowing in each loop is measured by means of a thermocouple and microvoltmeter. Great care was taken in the construction of those parts of the lining-up arrangements above and below the feed point X in Fig. 3 because the equality of characteristics of these two parts is relied upon to obtain co-phasal currents in the two line-up loops. In operation a current at the signal frequency is applied at X and the currents in each line-up loop measured. If the currents are equal, as has been found in practice to be the case, the receivers are adjusted to give a straight line at 45° to the deflection axes of the oscilloscope. Should the

currents be unequal, due to some slight dissimilarity in the two line-up systems, the equipment would be lined up to give a line deflection at the inclination appropriate to the measured loop currents.

Resistances of 72 Ω are inserted in the coaxial line near X to reduce circulating currents in the line-up loops and coaxial line and thus to minimize coupling between the receiving loops by way of the lining-up circuit. This coupling has been found to be quite negligible as is also the coupling between one line-up loop and the remote receiving loop.

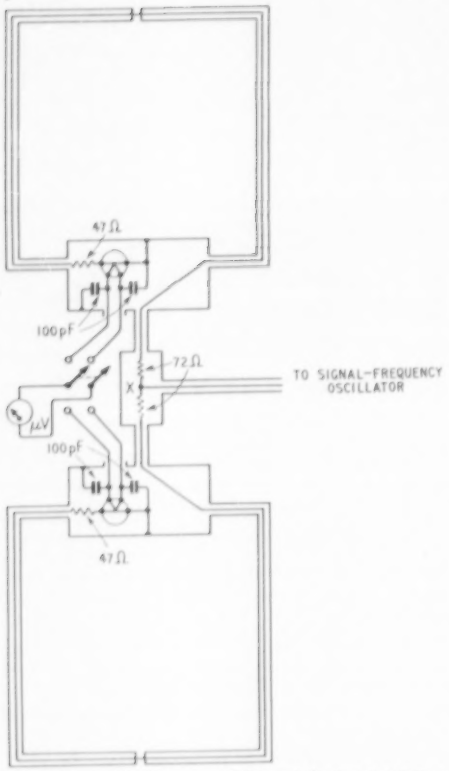

Fig. 3. *Schematic diagram of line-up loop arrangements.*

4. Tests and Calibration of the System

For testing the efficacy of the scheme for eliminating pick-up on the electric dipoles from vertically-polarized electric-field components in the incident signal a vertical transmitting aerial was set up at a distance of about 100 metres from the mast carrying the whole system and was energized at a number of frequencies in the h.f. band in turn. There should be no signal pick-up on the magnetic dipole but the electric dipole will receive a signal except when it is in a position normal to the plane of propagation. Tests showed that such conditions obtained, provided that the planes of the receiving loops were accurately horizontal and that there was no spurious radiation from local wires and other metallic objects. It is worthy of note that the mast was originally guyed with steel cable broken by insulators into 4-metre lengths and that, with that arrangement, it was impossible to obtain a good minimum on rotating loops while receiving signals from the vertical transmitting aerial. Reductions of the guy sections to 2 metres eliminated the majority of the spurious radiation and deep minima were then obtainable.

The system was calibrated by means of signals radiated from a balloon-supported transmitter feeding a horizontal dipole and capable of operation at a maximum height of 200 metres. Because of this height limitation and the desire to calibrate up to at least 20° angle of elevation, the balloon had to be operated at a distance from the aerial

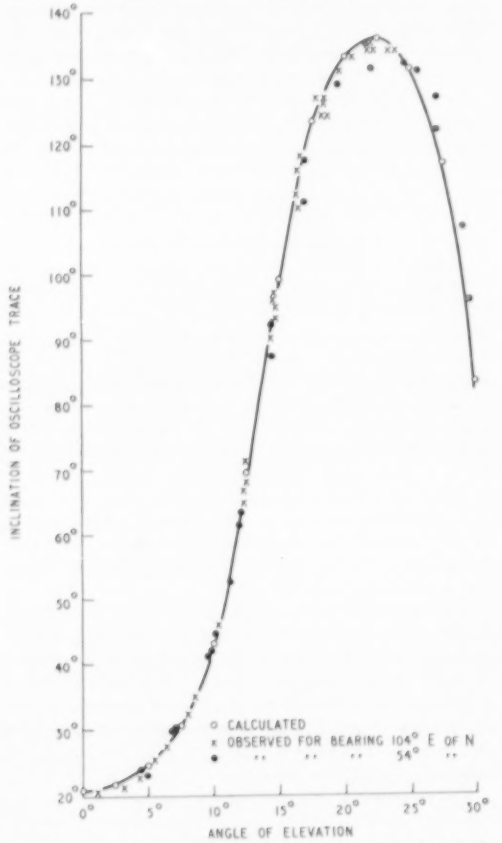

Fig. 4. *Calibration curve of angle of elevation system for 18·40 Mc/s.*

system of about 500 metres. In these circumstances the rays incident on the system are not parallel, as assumed in the theory, and this gives rise to a very small difference between the calculated fields at a given height for the two cases. The resultant fields at each aerial will also not be in quadrature with the field at C in Fig. 1. Calculations for the range of frequencies of interest show that, for angles of elevation up to 20°, the difference between the calculated inclination of the line on the oscilloscope for the parallel-ray case and the inclination of the major axis of the thin ellipse calculated for the conditions of calibration is about 1° maximum for angles of elevation of 10°–20° and a fraction of a degree for angles of elevation less than 5°. These differences are not likely to lead to any notable error in measuring angles of elevation in the range 5° to 20°.

Figs. 4 and 5 show calibrations of the system on two frequencies, each for two azimuths, and the calibration calculated on parallel-ray theory. It will be noted that the correspondence between observation and calculation is very close over the whole range of angle of elevation covered and that there is no substantial difference in the calibrations for the two azimuths.

Calibrations made over a frequency band of about 10 Mc/s to 20 Mc/s and over a wide range of azimuths show results as satisfactory as those of Figs. 4 and 5.

It was concluded from these results that the system could be used with a single calculated calibration curve for any given frequency for any azimuth and for elevation angles up to about 20°. There appears to be no reason why the theoretical calibration should not be extended for use at larger angles.

The agreement between the calculated and observed calibrations is partly due to the nature of the site which is of high conductivity clay and is substantially flat in all directions for at least 400 m. Although there are some large trees in several directions, the nearest is about 200 m distant from the aerials. A wire fence 1 m in height which runs close to the aerials has not given rise to any difficulties.

The electrical and mechanical stability of the system has been found to be of a high order; recent calibrations made on a number of frequencies have been found to agree very closely with those made on the same frequencies about eighteen months earlier.

A disadvantage of the system as described is the possibility of ambiguity in its indications. Thus, the calculated calibration curve of the present system for 18·40 Mc/s (see Fig. 4) shows that a signal giving a line pattern on the oscilloscope at, say, 100° could be incident at an angle of elevation of 15·1° or 29°. This ambiguity could be resolved by the addition of a third loop below the lower one in the present installation; measurements would be made in turn on the present pair of loops and on the lower pair and the angle common to the two measurements taken as the true value. This method of resolving ambiguity was used successfully in the radar installations referred to in Section 2. For the experiments for which the present system was designed it was expected from previous experience that the angles obtaining would not exceed 20° for frequencies above about 15 Mc/s, but for general use it is recommended that the third loop should be installed.

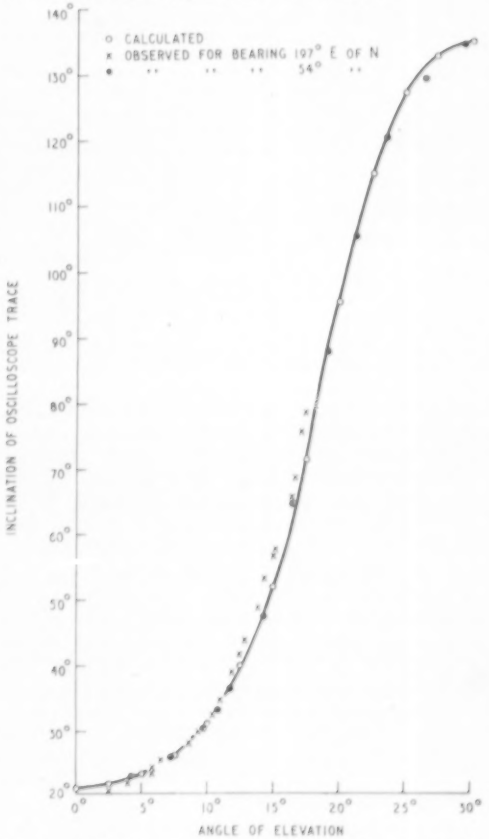

Fig. 5. *Calibration curve of angle of elevation system for 13·75 Mc/s.*

5. Method of Operation of the Equipment

After lining up the apparatus in the manner indicated, it is ready for operation on the signal to be measured. In order to facilitate the measurement of the inclination of the signal trace, the oscilloscope screen is provided with a circular protractor the centre of which corresponds to the

origin of the deflecting axes. A rotatable disk on which a radial line is drawn is mounted in front of the screen with its centre over the centre of the protractor.

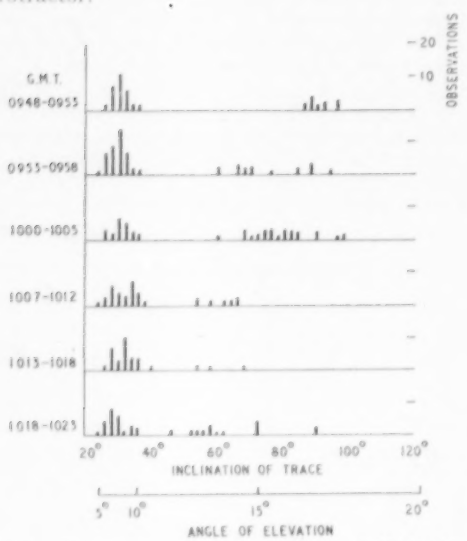

Fig. 6. *Observations of angle of elevation of* 16·245-*Mc/s signals from Colombo on* 12*th December* 1952.

In general, signals consist, not of a single ray as considered in Section 3, but of several rays which have travelled by different paths between transmitter and receiver. It is because of this fact that pulse transmission is much to be preferred in that the oscilloscope display then usually consists of a number of straight line deflections at inclinations to the oscilloscope axes corresponding to the angles of elevation of the individual rays. The measurement is not, in fact, greatly handicapped by interference effects between the various rays constituting the total signal but it may sometimes be found that such interference between two or more echoes overlapping in time of arrival cause the pattern to include ellipse forms of varying eccentricity and inclination. In such cases it is usually possible to observe the fading of the individual echoes and to read the inclination when one of them predominates in amplitude.

When telephone and telegraph signals are observed, the oscilloscope pattern will almost always consist of an ellipse of varying eccentricity and inclination. The method adopted in dealing with such cases is to read the inclination of the straight line or thin ellipse which often forms and lasts for a few seconds when the fading signal reaches its peak amplitude. This condition is assumed to correspond to the momentary preponderance in amplitude of one of the modes of propagation comprising the signal; readings are not taken if the straight line or thin-ellipse condition only lasts for a fraction of a second as such a condition might merely indicate a passage through the in-phase condition of two or more e.m.fs of random phase relationship.

It has been found convenient to take as many readings as possible during consecutive intervals of five minutes of the inclination of the straight-line traces in the case of pulse reception, or of the line or thin-ellipse traces at signal maximum with telephone and telegraph reception. The results are then plotted in the form of a histogram and an example of measurements taken in this way is shown in Fig. 6 for the case of reception at Slough of telegraph signals from Colombo on a frequency of 16·245 Mc/s. It may be concluded from this example that rays were present at an angle of elevation of about 8° (the most prominent group) and at various angles between 13° and 18°.

The justification for the observing procedure adopted for c.w. transmissions is apparent if pulse and c.w. transmissions from the same station can be observed alternately. Provided the pulse-echo pattern displays only a few components of comparable amplitude, it is found that their angles of elevation correspond closely to those measured on the c.w. signal in the manner described. If there are many echoes of similar amplitude the probability of one echo predominating for a period long enough to give a steady straight line or thin ellipse is remote and in such conditions reliable measurements would be impossible.

A more direct justification is provided by the following phenomenon. It has frequently been observed during the reception of high-speed telegraph signals that, in addition to the normal bright ellipse, the oscilloscope pattern includes a number of faint straight lines or thin ellipses, the largest of which are comparable in amplitude to the axes of the bright ellipse. The bright pattern corresponds to the resultant of all the rays composing the signal, while the fainter patterns

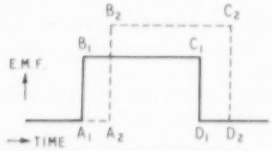

Fig. 7. *Illustrating the reception of a morse dot by two different paths.*

correspond either to the individual rays or to interference effects between two or more rays. The explanation of the phenomenon is probably as follows. In Fig. 7, $A_1\,B_1\,C_1\,D_1$ represents, in idealized form, the e.m.f. applied to the receiver by a single morse dot which has arrived

after reflection by the ionosphere. $A_2 B_2 C_2 D_2$ represents the same dot on arrival by way of a slightly longer trajectory. During the interval $A_1 A_2$ an e.m.f. $A_1 B_1$ will be applied to the receiver and, as this is produced by a single incident ray, the oscilloscope pattern will be a straight line of low brilliance because of the shortness of the interval $A_1 A_2$. During the longer interval $A_2 D_1$ the oscilloscope will display a much brighter pattern corresponding to the interference effects of e.m.fs $A_2 B_2$ and $A_1 B_1$. In the brief interval $D_1 D_2$ a pulse corresponding to the later-arriving component will be seen as a straight line at a different inclination from that produced in the interval $A_1 A_2$. When there are three or more different trajectories and corresponding components in the received signal, similar arguments lead to the conclusion that the first and last components to arrive will be displayed as straight lines and that ellipses of low brilliance will also be present corresponding to the short periods at the beginnings and ends of the dots and dashes when fewer than the maximum number of components are present. The phenomenon is very useful in that it helps to elucidate the mode of propagation of some of the components of the signal, and facilitates the measurements of their angles of elevation. It may readily be seen from a study of the variations of the pattern on the oscilloscope how the behaviour of the bright ellipse is related to the strength of the less brilliant 'pulse' deflections and, in particular, how the bright pattern develops into a straight line overlaying the corresponding pulse deflection when the other echoes decrease to a relatively low amplitude.

Acknowledgments

The assistance is acknowledged of Messrs. F. Kift and C. Medhurst in the development of the system and of Messrs. A. G. Wilson and R. A. J. Savage, B.E.M., in the design and construction of the equipment.

The work was carried out as part of the programme of the Radio Research Board and this paper is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

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[5] W. Ross, "The Development and Study of a Practical Spaced-Loop Direction Finder for High Frequencies", *J. Instn elect. Engrs*, Part III, 1947, Vol. 94, p. 99.

[6] F. Horner, "Properties of Loop Aerials", *Wireless Engineer*, 1948, Vol. 25, p. 254.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

High-Stability Oscillators

SIR,—Referring to my letter, published in the September 1955 issue of *Wireless Engineer*, I wish to correct an error which has crept into the formulae, and which arose when changing the notation used in my original paper* to that given in my letter. In the formula for the series-resonance circuit the expression $R_v^2\omega^2C_vC_g$ should read $R_v^2\omega^2C_aC_g$ and consequently the factor C_v/C disappears in the simplified formula. This means that the formula for a series-resonance oscillator becomes similar to that for an ordinary Colpitts oscillator, and therefore the conclusion contained in the four last lines of my paper is not correct.

What I say concerning better reduction of the grid voltage harmonics by a series-resonance circuit, is, generally speaking, right; in case of small amplitudes, however, the influence of these harmonics is negligible in comparison with that of harmonics caused by the non-linearity of the anode-current characteristic for fundamental grid excitation. In conclusion, one must concede that actually the value of Q and not of the ratio L_v/C_a has the decisive influence on the frequency stability of both types of oscillators with respect to the non-linear effects, this being in agreement with Commander Bernard's statement.

JANUSZ GROSZKOWSKI

Radio Institute,
Warsaw Technical University.

7th October, 1955.

*J. Groszkowski, "Frequency Stability of *LC* Oscillators with Large Grid and Anode Capacitances", *Bull. Acad. Polon. Sci.*, 1955, *Vol.* 3, *No.* 3.

SIR,—Since both Mr. Gouriet and Mr. Clapp* have conceded that the theoretical development, with which I took issue, was incorrect I was surprised to see the letters of Dr. Groszkowski and Mr. Reid published in *Wireless Engineer* for September 1955.

It is true that the percentage of the anode harmonic voltage which will be impressed upon the grid of a series-tuned oscillator will be less than in the case of a Colpitts, but the amount of harmonic voltage developed at the anode of a Colpitts oscillator for a given harmonic anode current will be correspondingly less, so that the net voltage at the grid for the same anode current will be the same in either case. Dr. Groszkowski made an error in assuming that the harmonic voltages at the anode could be the same. It is customary practice to operate the oscillator valve into an impedance much lower than its anode impedance at the operating frequency. At a harmonic of the oscillator frequency this circuit impedance from anode to cathode would be much lower so that the valve anode can accurately be described as a constant-current generator.

W. B. BERNARD

U.S. Navy Electronics Laboratory,
San Diego,
California, U.S.A.

10th October 1955.

[In its original form this letter contained a mathematical appendix but, in view of the general agreement that appears to have been reached, it has been omitted. Ed.]

*Proc. Inst. Radio Engrs, July and August 1955.

SIR,—By a coincidence W. B. Bernard and I wrote on the same day, respectively to *Wireless Engineer* and to *Proc. Inst. Radio Engineers*, pointing out that in the circuits discussed by Gouriet and Clapp, the frequency

change due to a phase change of the fundamental anode current should be independent of the L/C ratio. On this particular point Clapp has gracefully admitted that he followed the error of Gouriet, so here there is general agreement.

However, Bernard's correspondence with Clapp in *Proc. Inst. Radio Engineers* of August 1955 seems to me less helpful because of the uncertainties both of terminology and of the assumptions made.

Bernard's new letter (10th October 1955) to *Wireless Engineer* deals with the effect of harmonic currents in the resonator system which is a different and more difficult subject and one I am not now able to discuss.

The letter from Professor Groszkowski (*Wireless Engineer*, September 1955) also deals with harmonic currents in the resonator system and, as he has for many years been somewhat of an authority on this subject, I shall read his promised paper with interest.

I must confess, however, that I *am now* much less interested in harmonic effects because close adherence to Class A operation is not difficult, and because instabilities due to electrode capacitances, cathode-interface impedances, and electrode transit times, are predominant.

The letter of D. G. Reid (*Wireless Engineer*, September 1955) suggests that stability is a function of the L/C ratio, not in the presence of any harmonic effects but in the presence of an electrode capacitance instability. The argument put forward is surely valid only if constant loop resistance be assumed rather than constant Q value.

For resonators of equal excellence (Q), R will be proportional to L, and to maintain oscillations with a larger R we must either decrease C_g or increase g_m. If the former alternative be adopted the effect of the unstable C_g will be independent of the L/C ratio, and if the latter plan be used we will obtain much the same result because in practice we cannot increase g_m without increasing the instability of C_m.

NORMAN LEA

Research Division,
Marconi's Wireless Telegraph Co. Ltd.,
Chelmsford.
24th October 1955.

Equivalent Equalizer Circuits

SIR,—In his paper in *Wireless Engineer*, December 1955, p. 323, Mr. Rowlands describes a parallel-path equalizer circuit and shows that, for any setting of the variable tappings, it is possible to find a tandem connection of simple constant-resistance equalizers which gives an identical transmission characteristic.

Unfortunately, both the title and the method of treatment may lead the reader to suppose that the converse is also true, namely, that given a tandem connection of simple constant-resistance equalizers one could duplicate its performance by choosing suitably the time constants and tappings in Mr. Rowlands' circuit.

The reason why this is not so is as follows. The natural modes of the tandem-connected equalizer are restricted only in that they must lie in the left half of the complex p-plane. The natural modes of Mr. Rowlands' circuit, on the other hand, being the negative reciprocals of the time constants, must all lie on the negative real axis in the p-plane. If, therefore, the tandem-connected equalizer has any complex natural modes, as it may well do if it contains any resonant sections, there is no possibility whatsoever of providing these with Mr. Rowlands' circuit.

The point can be seen more specifically by examining that part of the Table, given in the paper, which deals with 2nd-order networks. Here, S_1 and S_2, the natural modes of the equivalent parallel-path circuit are given explicitly in terms of the parameters of the constant-resistance resonant equalizer. If these latter are such that $(\omega_0 L) < 2(R + r)$ then the values required for S_1 and S_2 are complex and hence unrealizable.

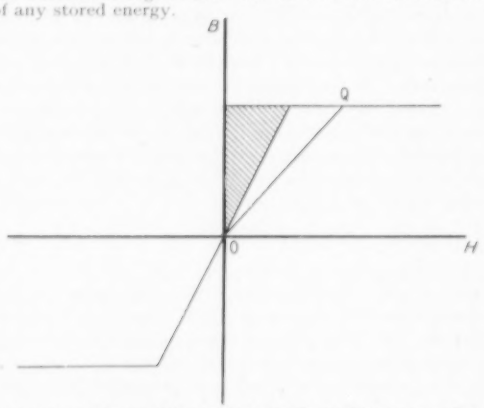
H. J. ORCHARD

Post Office Research Station,
London, N.W.2.
6th January 1956.

Saturable-Reactor Frequency Divider

SIR,—In reading the interesting note by Court and Scollay on the "Saturable-Reactor Frequency Divider" (*Wireless Engineer*, Dec. 1955) I was surprised by the two statements on p. 329 that ". . . at point P . . . the value of inductance falls from L_u to L_s . . ." and ". . . the inductance . . . has a store of energy, and when L_u is replaced by L_s, this energy will be dissipated . . ."

Inductance, like permeability, needs special definition when the magnetic circuit is non-linear and, in the absence of any definition by the authors, I can only consider three obvious possibilities. The first is incremental inductance, corresponding to incremental permeability, and this does fall sharply at saturation, but it is irrelevant to the total stored energy of the core. The second is the mean inductance, or ratio of total flux linkages to total magnetizing current; this is represented graphically by the slope of the line OQ in the diagram, which joins the origin to any point in question, and does *not* fall rapidly as Q moves into the saturation region. The third is an 'energy inductance' L_e obtained by equating the total core energy to $\frac{1}{2}L_e i^2$. Now the core energy per unit volume is $\int H dB$ which, for the point Q, is represented by the shaded area in the diagram: this makes it clear that taking the core into the saturation region does not involve the elimination of any stored energy.



Perhaps the operation of the circuit could be somewhat as follows. If the core of L saturates before C is discharged to zero potential, the remainder of the discharge of C will be controlled by r alone, since with B constant in the saturated core there can be no e.m.f. in the coil. This results in (a) a pulse of output voltage across r and (b) an increased dissipation in r which means that on the return swing the coil will not be able to re-charge the capacitor to the potential it would have attained had L remained unsaturated throughout the cycle. Therefore the amplitude of the next cycle will not be sufficient to saturate L. The number of cycles to the next output pulse should then depend partly on R, through which the resonant circuit must acquire energy from the source in order to rebuild its amplitude of oscillation to the saturation level.

D. A. BELL

Birmingham.
12th January 1956.

NEW BOOKS

Vacuum Valves in Pulse Technique

By P. A. Neeteson. *Philips' Technical Library.* Pp. 170 + viii. Cleaver Hume Press Ltd., 51 Wright's Lane, London, W.8. Price 27s.

The title of this book is a little misleading, for it carries with it an implication that the book might be about the special characteristics of valves for pulse generation; e.g., high peak current but low mean current ratings, magnetrons, klystrons and the like. The book does not deal at all with these things, however; it deals with ways of analysing the *RC* circuits used in pulse generation and exemplifies them by detailed analyses of multivibrators.

The early chapters all deal with the calculation of the response of *RC* circuits under various conditions of switching. The use of the valve as a switch is then briefly discussed. Chapter 5 is on operational calculus and is followed by nearly 50 pages on fundamental treatment of electron tubes as switching elements. The treatment is thorough and covers the effects of grid current.

In the rest of the book bistable, monostable and astable multivibrators are analysed in detail.

The treatment throughout is highly mathematical in the sense that there is hardly a page which does not bear at least one equation and there are many which are nearly full of them. The level of mathematics is not at all a difficult one, however, there being little beyond second-order differential equations or their equivalent.

This use of mathematics and, in particular, the widespread references by symbols, makes the book difficult reading.

It is a book more for study than for reference, for one cannot readily follow the argument until one has got the meaning of the more important symbols firmly into one's head. There is no summary of conclusions and the designer of a multivibrator can hardly hope to use the book as a short cut. He must study it in detail in order to extract design information from it.

W. T. C.

Proceedings of the Symposium on Printed Circuits

Pp. 122. Engineering Publishers, G.P.O. Box 1151, New York 1, N.Y., U.S.A. Price $5.

F.M. Explained

By E. A. W. Spreadbury, M.Brit.I.R.E. Pp. 37. Trader Publishing Co. Ltd., Dorset House, Stamford Street, London, S.E.1.

A Study of the Double Modulated F.M. Radar

By Mahomed Abd-El Wahab Ismail. Mitteilungen aus dem Institut für Hochfrequenztechnik, No. 21. Pp. 112. Verlag Leeman, Arbenzstrasse 20, Postfach Zürich 34, Switzerland. Fr. 10.40.

Television Principles and Practice (2nd Edition)

By F. J. Camm. Pp. 215. George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Price 25s.

The Mobile Manual for Radio Amateurs

Pp. 313. American Radio Relay League, West Hartford, Connecticut, U.S.A. Price $3.

B.B.C. Handbook 1956

Pp. 287. The British Broadcasting Corporation, 35 Marylebone High Street, London, W.1. Price 5s.

Radio Operating Questions and Answers (12th Edition)

J. L. Hornung and A. A. McKenzie. Pp. 571 + xii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 34s.

Instruments for Measurement and Control

By Werner G. Holzbock. Pp. 371 + vi. Chapman & Hall Ltd., Essex Street, London, W.C.2. Price 80s.

This is an American book which is descriptive in its first half of instruments for measuring temperature, humidity, moisture, pressure, flow, liquid level, density, viscosity and speed. The second half of the book deals with methods of control under the influence of the initial measurement. The methods described are mainly non-electrical

Fixed Resistors

By G. W. A. Dummer, M.B.E., M.I.E.E. Pp. 187 + xi. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 28s.

This book, which is Vol. I of a series dealing with radio and electronic components, deals chiefly with wire-wound, general purpose, and high-stability fixed resistors. It describes their constructional form and explains their characteristics. Methods of measurement are also described.

Static and Dynamic Electron Optics

By P. A. Sturrock, Ph.D. Pp. 240 + x. Cambridge University Press, 200 Euston Road, London, N.W.1. Price 30s.

Part 1 covers static electron optics in five chapters, headed:—The variational equation, Classical geometrical optics, Instrumental electron optics, The rotationally symmetrical system and Systems of minor symmetry. Part 2, in two chapters, deals with uniform and periodic focusing of particle acceleration. The treatment is mathematical.

INDEX TO ABSTRACTS AND REFERENCES

The annual indexes to Abstracts and References appearing in *Wireless Engineer* for the years 1946–1953 inclusive have been reprinted under one cover by the Institute of Radio Engineers. Copies can be obtained from the Institute of Radio Engineers, 1 East 79th Street, New York 21, N.Y., U.S.A., at the price of $2.25 in U.S.A. and Canada and $2.35 elsewhere. Special rates of $1.65 in U.S.A. and Canada and $1.75 elsewhere are available to colleges, public libraries and subscription agencies.

NEW YEAR HONOURS

In the New Year Honours List, Air Commodore W. E. G. Mann (Director-General of navigational services, Ministry of Transport and Civil Aviation) and W. J. Richards (Director of the Radar Research Establishment) have been appointed Companions of the Order of the Bath.

Captain Charles F. Booth (Assistant Engineer-in-Chief, G.P.O.) has been promoted to Commander of the Order of the British Empire.

C. W. Oatley (Fellow of Trinity College, Cambridge) becomes an O.B.E. and A. Bowen (B.T.-H. electronics engineering dept.), R. G. Hodges (Senior experimental officer, Radar Research Establishment), D. C. Rogers (Standard Telephones & Cables) become Members of the Order of the British Empire.

"WIRELESS ENGINEER" BINDING

Binding cases for *Wireless Engineer* can be supplied at 7s. 6d. (postage 6d.). The cost of binding is 22s. 6d. (postage 1s. 6d.) per volume including binding case.

EXHIBITIONS

6th–8th March. Television Society's Exhibition. At the Royal Hotel, Woburn Place, London, W.C.1. The first day is reserved for members; admission on the other days is by ticket obtainable from the Television Society, 164 Shaftesbury Avenue, London, W.C.2.

10th–12th April. R.E.C.M.F. Exhibition. At Grosvenor House, London, W.1. There will be a preview on the afternoon of 9th April for overseas and other specially invited guests. Application for admission has to be made in advance to the Radio and Electronic Component Manufacturers' Federation, 21 Tothill Street, London, S.W.1.

13th–15th April. London Audio Fair. At the Washington Hotel, Curzon Street, London, W.1. Admission by invitation card, obtainable from radio dealers or from London Audio Fair, 17 Stratton Street, London, W.1.

23rd April–4th May. British Industries Fair (Electrical Section). At Olympia, London, W.14. Open to the public in the afternoon.

25th and 26th April. Public Address Show (Association of Public Address Engineers). At Conway Hall, Red Lion Square, Holborn, London, W.C.1. Open to the public each afternoon.

9th–19th May. Mechanical Handling Exhibition. At Earls Court, London, S.W.5. Open to the public.

14th–17th May. Physical Society's Exhibition. At Royal Horticultural Hall, Westminster, London, S.W.1. Application for tickets should be made to the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

26th and 27th May. B.S.R.A. Exhibition. At the Waldorf Hotel, Aldwych, London, W.C.2. Application for tickets should be made to the British Sound Recording Association, 295 Regent's Park Road, London, N.3.

12th–18th July. Institution of Electronics Exhibition. At the College of Technology, Manchester. Applications for tickets should be made to W. Birtwistle, 78 Shaw Road, Thornham, Rochdale.

22nd August–1st September. National Radio and Television Exhibition. At Earls Court, London, S.W.5. There will be a preview on 21st August for overseas and other specially invited guests. Open to the public daily, except Sunday.

3rd–10th September. Farnborough Air Show (Society of British Aircraft Constructors). At Farnborough, Hants. Open to the public.

MEETINGS

I.E.E.

8th February. "Pulse Techniques with particular reference to Line and Radio Communication", by E. M. Deloraine, Dr.Ing.

20th February. "Ultrasonics in Industry", talk with films and demonstrations by C. F. Brockelsby.

1st March. Discussion on "Recruitment to the Engineering Profession" and the film "The Inquiring Mind".

These meetings will commence at 5.30 at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Brit.I.R.E.

29th February. "Technique of Microwave Measurements", discussion to be opened by E. M. Wareham at 6.30 at the London School of Hygiene & Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

21st February. "Some Problems in a Band-Sharing Colour Television System", by A. V. Lord, B.Sc.

28th February "Development of 21" Colour Television Receiver" by H. A. Fairhurst.

These meetings will be held at 7 o'clock at the Institute of Education, Malet Street, London, W.C.1. Admission 2s. 6d. for non-members.

Society of Instrument Technology

9th February. "The Scope for Feedback Control and Automatic Calculation in Industrial Mechanization", by Professor A. Tustin, M.Sc., at 6 o'clock at Manson House, 26 Portland Place, London, W.1.

British Kinematograph Society

8th February. "Practical Acoustics and Cinema Auditoria", by J. Carson.

15th February. "Synchronous Sound Recording using the Syncropulse Process", by N. Leevers, B.Sc., A.C.G.I.

These meetings will be held at the Borough of Holborn Town Hall, High Holborn, London, W.C.1, and will commence at 7.15.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for December 1955

Date 1955 December	Frequency deviation from nominal: parts in 10^8	
	MSF 60 kc/s 1429-1530 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.
1	−0·2	+2
2	−0·2	+2
3	NM	+2
4	−0·2	+1
5	−0·2	+2
6	−0·2	+3
7	−0·2	+3
8	−0·2	+3
9	−0·2	+3
10	−0·2	+4
11	−0·2	+2
12	−0·2	+3
13	−0·2	+4
14	−0·2	+4
15	−0·2	+5
16	−0·2	−3
17	−0·2	−2
18	−0·2	−2
19	−0·2	−2
20	−0·2	−2
21	−0·2	−3
22	−0·1	−2
23	−0·2	−3
24	NM	NM
25	NM	NM
26	NM	NM
27	NM	−2
28	−0·1	−2
29	−0·1	−1
30	−0·1	−1
31	−0·1	−2

The values are based on astronomical data available on 1st January 1956.

N.M. = Not Measured.

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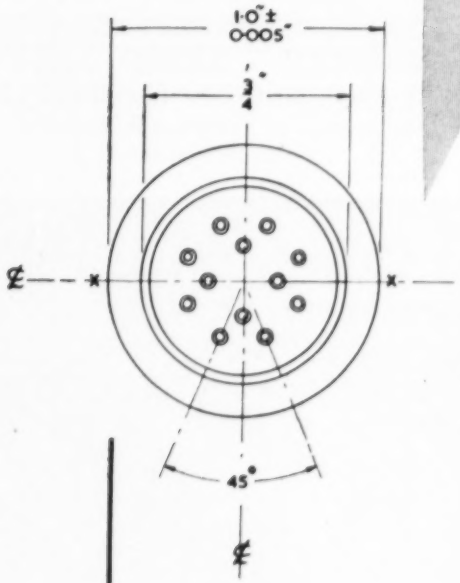

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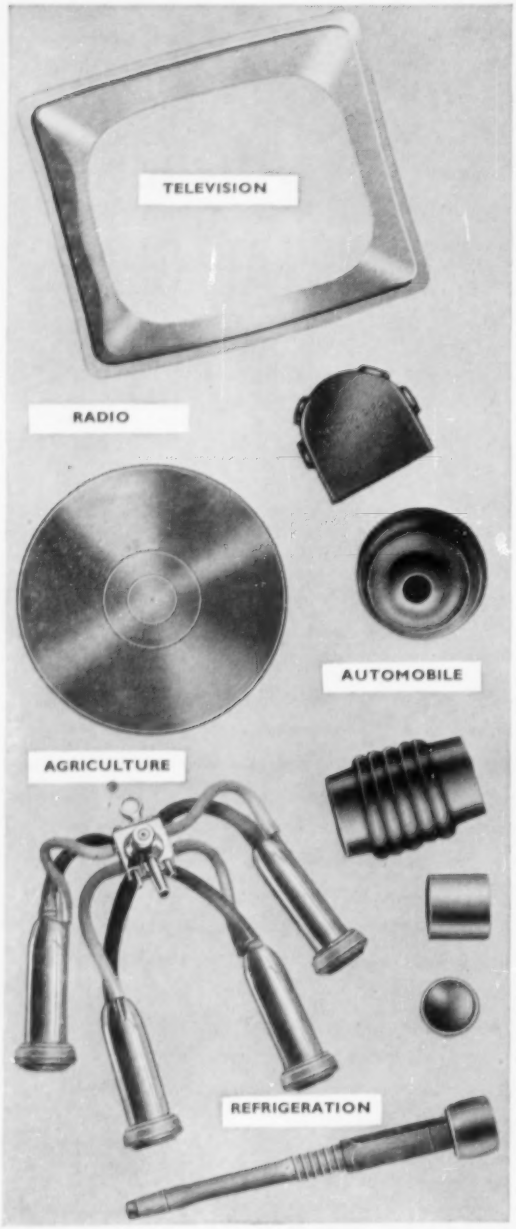

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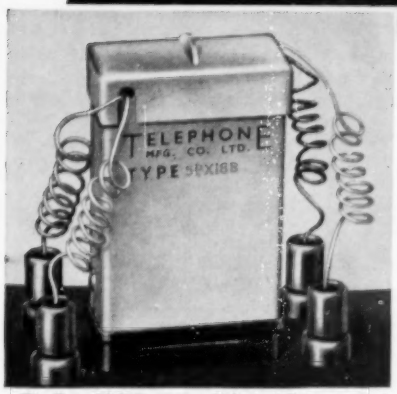

The Type 5PX Carpenter Polarised Relay is fitted with platinum contacts to reduce thermal noise, and has flying contact leads to reduce "pick-up" in contact circuit due to the coil. DIMENSIONS : *Height* 2.5 *in. Width* 1.6 *in. Depth* 0.8 *in. Approx. weight* 4.8 *oz.*

Simplify Recording, Control and Test circuits

The fast operating Carpenter Polarized Relay Type 5PX is being used very satisfactorily in a wide variety of control, recording and test circuits where the available initiating voltage is extremely low and must be greatly amplified before it can be used. The relay enables this to be done efficiently and economically by converting ("chopping") d.c. input signals to a square-wave alternating voltage which may then be amplified simply in an a.c. amplifier.

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The Type 5PX relay has platinum contacts so that contact noise voltages are considerably reduced. Moreover, screening between coil and contact circuits—and flying contact leads, reduce to negligible proportions possible trouble due to " pick-up " from the coil. Where frequencies in excess of 50 c/s are required, specialized versions of the larger Type 3 relay can be used.

These " chopper " relays are successfully incorporated in laboratory test gear, supervisory circuits, temperature recorders, etc., and the Manufacturers will gladly make available to you their experience in this field of electronic equipment.

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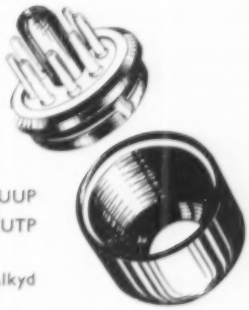

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Plessey 100-Watt Heavy Duty Vibrator

Developed in conjunction with S.R.D.E.

Specification

Operating Voltage	24v. nominal*
Operating Frequency	110 c/s nominal
Drive Coil Power	5 watts max.
Contact Closure	
Primaries	72%—84%
Secondaries	62%—74%
Working Life	1,000 hrs. nominal at 20° C.
	500 hrs. nominal at 70° C.
Voltage Proof (at pressures down to 70 mm. Hg.)	750v. r.m.s. 50 c/s. between all parts not electrically connected.
Input Rating (24v. nominal supply)	5—8 amps.
Temperature Category	40/70 (— 40° C. to + 70° C.)
Humidity Class	H.1 meets requirements of R.C.S.172.
Bumping	Meets requirements of R.C.S.172.
Weight	12.6 oz.

* A 12-volt version of this vibrator is at present under test and will become available as soon as conditions of life and rating have been determined.

P.D. 1a

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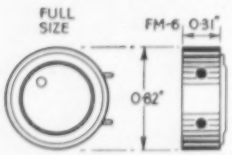

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Alternative physical shapes of identical performance are available, FM-4, 1·02" x 0·82" and FM-5, 0·82" x 0·82".

Impedance			Response
Standard	2500 Ω.	1000 Ω d.c.	for 6 db down
FM6-D	600 Ω.	150 Ω d.c.	350 — 3900 c/s

Weight
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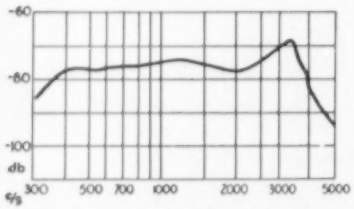
0.4 oz.

Output at 1000 c/s
—75 db re
1v per dyne per cm²



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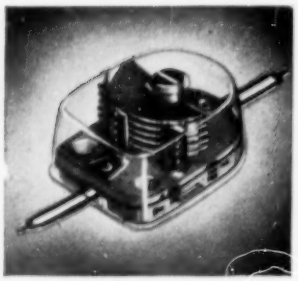

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Fundamentals of Electroacoustics

By F. A. FISCHER
Fernmeldetechnisches Zentralamt, Darmstadt

Translated by STANLEY EHRLICH, *Raytheon Manufacturing Co., Waltham, Mass.*, and FRITZ PORDES, *U.S. Navy Underwater Sound Laboratory, New London, Conn.*

CONTENTS: Electric and Mechanical Oscillators. Forces Exerted on Matter by Electric and Magnetic Fields. Electroacoustic Energy Conversion Principles and Their Basic Laws. Systematic Presentation of Electroacoustic Transducers. The Differential Equations of Electroacoustic Transducers. Electric and Acoustic Impedance of Transducers. The Radiation of Sound. The Efficiency of a Transducer as a Sound Source. The Sensitivity of a Transducer as a Sound Receiver. Broad-band Transducers. Electromechanical Coupling. Transducers Employing Electric Resistances. List of Symbols, Terms and Units. Bibliography. Index.

The book is written for those who intend to engage in the solution of electroacoustical problems in a thorough and exhaustive manner, and its purpose is to present the necessary fundamental theory in closed form.

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Applications are invited for pensionable posts as

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in the

PATENT OFFICE

to undertake the official scientific technical and legal work in connection with Patent Applications. There are a small number of similar posts in the Ministry of Supply. Applications may be accepted up to 31st December, 1956, but early application is advised as an earlier closing date may be announced. Interview Boards will sit at frequent intervals.

Candidates must be between 21 and 28 years of age during 1956 (up to 31 for permanent members of the Experimental Officer Class) and have First or Second Class Honours degree in physics, chemistry, mechanical or electrical engineering, or mathematics. Candidates taking their degrees in 1956 may apply before the result of their degree examination is known.

Starting emoluments in London, including Extra Duty Allowance for 45½-hour week, between £554 and £794 (men), £712 (women), according to periods of National Service and post-graduate experience, rising to £939 (men) and £869 (women). Promotion to Examiners—£977 to £1,344 (men), £896 to £1,247 (women); normally after five years (three or four years in exceptional cases). Women's scales subject to increase under equal pay scheme. Good expectation of promotion to Senior Examiner (£1,344 to £1,620 men) with reasonable expectation of further promotion to Principal Examiner (£1,620 to £1,850 men). Candidates are recruited by selective interview.

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If you have had a good general education with a degree in Engineering, Science or equivalent.

If you are interested in Radio Propagation and/or Microwave Techniques.

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Middlesex,
who will arrange an informal interview.

Expenses of travel will be met.

SEMICONDUCTORS. The Mullard Radio Valve Company has a number of openings in its expanding Semi-Conductor Division for Electrical Engineers. These posts offer an excellent opportunity for suitably qualified young men to enter this new field; either in work which involves investigations into the properties of semiconductor devices and pursuing their developments, or in the sphere of studying measurements and applications of these devices.

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There are also a number of posts suitable for men of Ordinary National Certificate standard.

In the first instance, these appointments will be at the Company's plant at Mitcham, Surrey, but will eventually be transferred to a new establishment which is in the course of erection at Southampton and which will specialize in this aspect of electronic engineering.

The commencing salaries offered will be dependent on age, experience and qualifications and will be in keeping with present-day levels; and these posts offer excellent opportunities for advancement within the Organization.

Please apply in writing to the Personnel Officer, The Mullard Radio Valve Co. Ltd., New Road, Mitcham Junction, Surrey, quoting reference GBK/S5.

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The Engineering Department, Electronics Division of Westinghouse Electric Corporation, has available a number of attractive situations. Applicants must have professional standing in the Institute of Electrical Engineers or equivalent standing in the Institute of Radio Engineers.

Applicants for these positions should be over 25 years of age with at least three years' experience in design or development in one or more of the following fields:

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The work is concerned with guided missile and navigational systems, automatic pilots, analogue computors, flight simulators, servos and automatic control developments.

Salaries are good, conditions and amenities attractive.

Pension Scheme, assistance with housing and with removal expenses.

Interviews either in London or Belfast.

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Applications to:—

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FEDERATION OF NIGERIA

A vacancy exists for an Electrical Engineer (Meteorological Service) in the Federation of Nigeria (BCD 57/14/04).

Duties include determination of types of radio and radar meteorological equipment to be installed, supervision of maintenance and modification and possible operation of such equipment and work in connection with meteorological signals traffic.

Candidates should hold a university degree in electrical engineering or should have passed such examination as will exempt them from Parts A and B of the examination for A.M.I.E.E. and must have special experience of radar and should preferably have experience of meteorological radio and radar aids. Exceptionally, candidates may be considered with lesser qualification if they have very good theoretical electrical knowledge and have considerable experience in meteorological radio and radar aids.

Appointment is either pensionable on probation in the salary range £1,086 to £1,680 per annum or on contract in the salary range £1,290 to £1,956 per annum. For candidates without full professional qualifications pensionable salary £876-£1,680 per annum, contract salary £1,080-£1,956 per annum. A gratuity of £37 10s. for every three months' satisfactory service, payable on completion of a contract appointment. Government quarters are provided if available, at a rental of 8½ per cent basic salary with a maximum of £150 per annum. Free first-class passages for the officer and his wife. Assisted passages, for children up to the cost of two adult fares and a conditional grant of £75 per annum for a maximum of two children maintained in the United Kingdom. Leave is granted at the rate of seven days for each month of resident service in a tour of 18 to 24 months.

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Cosmos Works · Brimsdown · Enfield · Middlesex

has vacancies in its Research and Development Laboratories for:

1. **Circuit Development and Application Engineers** for Colour Television investigations.
2. **Circuit Development and Application Engineers** for Black and White Television development work.
3. **Engineers** for development work on Television and F.M. Amplifier problems. Previous experience in V.H.F. or F.M. required.
4. **Cathode Ray Tube Development Engineers** for development work on Colour and Black and White tubes. Previous experience on cathode ray tube development or design required.
5. **Application Engineers** for work in connection with Customer problems on Television, Radio and F.M.
6. **Engineer** for design of test equipment for Colour, Black and White Television and allied development work.
7. **Engineers** for Circuit development and Application work on Transistors.

★ ***The above applicants should have a good Engineering or Physics degree or equivalent, but vacancies also exist for candidates with H.N.C. or equivalent qualifications.***

★ ***The vacancies are a result of a large expansion in the Company's activities.***

★ ***Good salaries will be paid to suitable applicants and the positions are progressive and carry the advantages of a Pension Scheme.***

★ ***The starting salary will depend on the qualifications, experience and age of the applicants.***

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ELECTRONIC ENGINEERS of degree status and with some years' experience are invited to apply for a number of newly-created senior posts with the Guided Weapons Division of The English Electric Co. Ltd. at Luton and Stevenage as follows:—

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SENIOR ENGINEER to act as Deputy Head of Section engaged on the development of experimental radar equipment involving overall system experiments. A broad experience of radar is essential and preferably a knowledge of army ground radar.

SENIOR ENGINEERS for work on general circuit development. A sound fundamental knowledge of electronics is required and the ability to apply it.

These posts are progressive, offering attractive salaries and giving full scope for initiative in an expanding organization. Housing assistance can be given in certain instances after a period. Arrangements for interviews either in London, Luton or Stevenage will be willingly made to suit candidates' requirements, including evening and weekend interviewing. Applications to Dept. C.P.S., 336/7 Strand, London, W.C.2, quoting Ref. No. SA.38M.

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are required for interesting and progressive work on semi-conductor development at

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The above requirements may be waived in the case of applicants with experience in a suitable technical field.

Salaries are based on qualifications, experience and age, and are in keeping with present-day levels. General prospects within the organization are excellent and there is a generous pension scheme. Apply to **Personnel Officer, Electronic Tubes Limited, Kingsmead Works, High Wycombe, Bucks.**

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Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

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Physicists or engineers with experience of electronic techniques, ability and enthusiasm, required for research and development work. Qualifications: honours or general degree or H.N. Cert. Some knowledge of acoustics would be of assistance but not essential.

Interesting and challenging work in expanding laboratories, permanent and with good prospects. Salaries will be paid according to qualifications, experience and ability but are based on generous scales and adequate payment during illness and pension schemes, etc., are in operation.

Apply: Personnel Manager, Kelvin & Hughes, Ltd., New North Road, Barkingside, Ilford, Essex, quoting reference RES.11/55.

NEW RESEARCH LABORATORY

IMPORTANT APPOINTMENTS

Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

The appointments offered provide scope for both senior and junior staff. Salaries will be competitive and in accordance with qualifications and experience. Applications are invited from:—

1. Honours graduates in physics or engineering for a wide range of research and development work on electronic computors and associated equipment.
2. Engineers with Higher National Certificate for development and design work on electronic computors and associated equipment.
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for individual design work or to lead a small drawing office section engaged on general electrical work or on small transformers.

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ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

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Applicants should have served a recognized engineering apprenticeship or have had similar workshop experience, and should possess a Higher National Certificate or an equivalent qualification. Considerable drawing office and design experience in electrical, electronic or electro-mechanical engineering is required.

Officers appointed will, after a probationary period, become members of the permanent staff of the U.K. Atomic Energy Authority. Working conditions are excellent, with ample modern equipment.

Salary according to age, qualifications and experience within the scale:

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1. Development Engineers for work on design and development of thermionic valves.
2. Technical Assistants for work in connection with design and development of thermionic valves.
3. Mechanical Engineers interested in the problems of mass production associated with thermionic valves.

These vacancies are the result of a rapid expansion in the Company's activities. The positions are progressive and carry the advantages of a Pension Scheme.

Applicants for vacancies (1) should have an Engineering or Physics degree, but applications from candidates with H.N.C. or equivalent will be considered.

Applicants for vacancies (2) and (3) should have Ordinary N.C. or H.N.C. or Inter B.Sc. or equivalent.

The starting salary will be in accordance with the qualifications, experience and age of the applicants.

Applications should be in writing and will be treated with the strictest confidence.

Apply to **Mr. J. Donegan, Chief Engineer, Valves.**

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COLLEGE OF TECHNOLOGY
(Faculty of Technology in the University of Manchester)

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LECTURER IN ELECTRICAL ENGINEERING

The Governing Body invites applications for a Lectureship in Electrical Engineering in the College of Technology, with the title and status of Lecturer in the University of Manchester. Special qualifications in ultra-high frequency techniques are desirable but applicants with other interests will be considered.

The Department covers a very wide range of aspects of Electrical Engineering, and all members of staff are expected to undertake, assist in or supervise research.

Salary: £650 per annum, rising by annual increments of £50 to £1,350 per annum.

Commencing salary according to qualifications. Superannuation under the F.S.S.U. Family Allowances.

Conditions of appointment and form of application may be obtained from The Registrar, College of Technology, Manchester, 1. The last day for the receipt of applications is **Wednesday, 29th February 1956.**

B. V. BOWDEN,
Principal of the College

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Index to Advertisers

	PAGE
Aero Research, Ltd.	10
Anderton Springs, Ltd.	28
Appointments Vacant	23, 24, 25, 26, 27, 28
Automatic Coil Winder & Electrical Equipment Co., Ltd., The	Cover ii
Belling & Lee, Ltd.	15
British Insulated Callender's Cables, Ltd.	14
Brookes Crystals, Ltd.	20
Cinema Television, Ltd.	4
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200 V.	—	—	—	—	—	CP141H	CP144H	CP147H
250 V.	—	—	—	CP120K	CP120K	CP121K	CP122K	CP123K
400 V.	—	—	—	CP124Q	CP124Q	CP125Q	—	CP127Q
600 V.	—	—	—	—	CP128T	CP129T	CP130T	CP127T
600 V.	—	—	—	—	CP142T	CP144T	CP147T	CP150T
800 V.	—	CP128V	CP128V	CP128V	CP131V	CP130V	CP132V	—
800 V.	—	—	—	—	CP143V	CP146V	CP149V	CP152V
1000 V.	—	—	CP141W	CP142W	CP145W	CP147W	CP149W	CP153W
1200 V.	—	CP131X	CP131X	CP131X	CP130X	CP132X	CP133X	CP134X
1500 V.	—	CP141GO	CP142GO	CP145GO	CP147GO	—	—	—
2500 V.	—	CP144KO	CP146KO	CP147KO	CP150KO	CP153KO	CP154KO	CP155KO
5000 V.	—	CP148SO	CP151SO	CP153SO	CP154SO	CP155SO	—	—
7500 V.	—	CP151UO	CP153UO	CP154UO	CP155UO	—	—	—
10,000 V.	CP151WO	CP153WO	CP154WO	CP155WO	—	—	—	—

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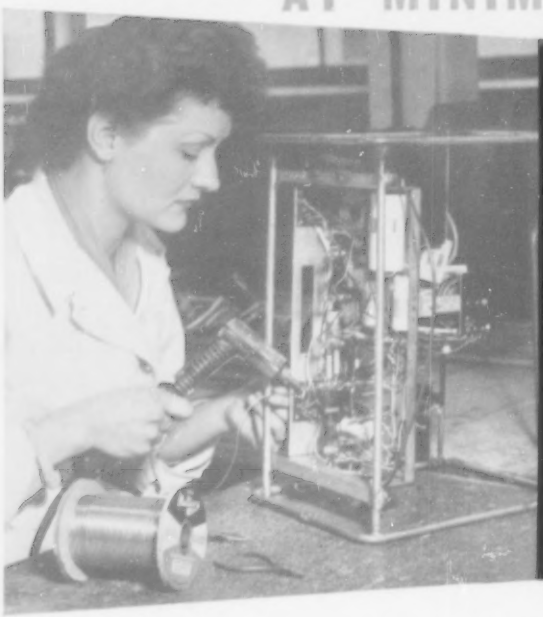

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